SERVICE AREA SYSTEM CHARACTERIZATION REPORT

Submitted on behalf of the following participating Permittees
By the Passaic Valley Sewerage Commission:

Passaic Valley Sewerage Commission (NJ 0021016)
Bayonne City (NJ0109240)
East Newark Borough (NJ0117846)
Harrison Town (NJ0108871)
Kearny Town (NJ0111244)
Newark City (NJ0108758)
North Bergen MUA (NJ0108898)
Paterson City (NJ0108880)

Passaic Valley Sewerage Commission
Essex County
600 Wilson Avenue
Newark, New Jersey

"Protecting Public Health and the Environment"

June 2018

SECTION A - INTRODUCTION AND BACKGROUND

A.0 SUMMARY OF CHANGES

A.1 TITLE OF PLAN AND APPROVAL

Title: Service Area System Characterization Report for Passaic Valley Sewerage Commission LTCP

Preparer:

Project Officer: ______________________ 6/20/18
Michael J. Hope, P.E., Greeley and Hansen LLC — Date

QA Officer: ______________________ 6/20/18
Timothy J. Dupuis, P.E., CDM Smith — Date

Passaic Valley Sewerage Commission:

PVSC Program Manager: ______________________ 06/20/2018
Bridget McKenna, Chief Operating Officer, PVSC — Date

PVSC QA Officer: Marques Eley 6/19/18
Marques Eley, PVSC — Date

New Jersey Department of Environmental Protection

DEP Permits: ______________________
Joseph Mannick, CSO Coordinator — Date

DEP QA: ______________________
Marc Ferko, Office of Quality Assurance — Date

Service Area System Characterization Report

Submitted by
Passaic Valley Sewerage Commission:

NJPDES Number NJ0021016 (Passaic Valley Sewerage Commission)

Approval of this submittal:

Permittee: ______________________ 06/20/2018
Bridget McKenna Date
Chief Operating Officer, Passaic Valley Sewage Commission

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 06/20/2018
Bridget McKenna Date
Chief Operating Officer, Passaic Valley Sewage Commission

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0109240 (Bayonne City)

Approval of this submittal:

Permittee: ______________________ 6.19.18

Timothy Boyle — Date

Superintendent, City of Bayonne Department of Public Works

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 6.19.18

Timothy Boyle — Date

Superintendent, City of Bayonne Department of Public Works

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0117486 (East Newark)

Approval of this submittal:

Permittee: ______________________________ 6/25/18

Frank Pestana
Licensed Operator, Borough of East Newark

Date

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________________ 6/25/18

Frank Pestana
Licensed Operator, Borough of East Newark

Date

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0108871 (Harrison)

Approval of this submittal:

Permittee: ______________________________ 6/19/18

Rocco Russomano Date
Town Engineer, Town of Harrison

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________________ 6/19/18

Rocco Russomano Date
Town Engineer, Town of Harrison

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0111244 (Kearny)

Approval of this submittal:

Permittee: 6/20/18

Robert J. Smith
Town Administrator, Town of Kearny

Date

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: 6/20/18

Robert J. Smith,
Town Administrator, Town of Kearny

Date

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0108758 (Newark)

Approval of this submittal:

Permittee: ______________________________ 6-18-18

Ras J. Baraka
Mayor, City of Newark

Date

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________________ 6-18-18

Ras J. Baraka
Mayor, City of Newark

Date

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0108988 (North Bergen Municipal Utilities Authority)

Approval of this submittal:

Permittee: ______________________ 6/25/18

Frank Pestana — Date
Executive Director, North Bergen Municipal Utilities Authority

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 6/25/18

Frank Pestana — Date
Executive Director, North Bergen Municipal Utilities Authority

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0108880 (Paterson)

Approval of this submittal:

Permittee: Manny Ojeda
Director of Public Works, City of Paterson

6/20/18.
Date

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: Manny Ojeda
Director of Public Works, City of Paterson

6/20/18
Date

A.2 DISTRIBUTION LIST

Passaic Valley Sewerage Commission
Bridget McKenna, Chief Operating Officer
Patricia Lopes, Director of Process Control Engineering and Regulatory Compliance
Marques Eley, Process Control Engineer III, PE

Participating Permittees:

Bayonne:	Timothy Boyle, Superintendent of Public Works
East Newark:	Frank Pestana, Licensed Operator
Harrison:	Rocco Russomano, Town Engineer
Kearny:	Robert J. Smith, Town Administrator
Newark:	Ras J. Baraka, Mayor of Newark
North Bergen:	Frank Pestana, Executive Director
Paterson:	Manny Ojeda, Director of Public Works

New Jersey Department of Environmental Protection
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Joseph Mannick, Surface Water Permitting
Marc Ferko, Office of Quality Assurance

A.3 PROGRAM CONTACT INFORMATION

Contact information for those parties involved in the System Characterization Report is as follows:

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Town of Kearny
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Water and Sewer
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Manny Ojeda
Director of Public Works
City of Paterson
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Paterson, NJ 07505

Frank Pestana
Licensed Operator
East Newark Borough
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Newark, NJ 07029

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Appendix A – Combined Sewer Overflow and Stormwater Sampling Results

A.5 SIGNIFICANT BACKGROUND

Passaic Valley Sewerage Commission (PVSC) provides wastewater treatment service to 48 municipalities within Bergen, Hudson, Essex, Union and Passaic Counties in the Passaic Valley Service District located in northeast New Jersey. In total PVSC services approximately 1.5 million people, 198 significant industrial users and 5,000 commercial customers. The PVSC District covers approximately 150 square miles from Newark Bay to regions of the Passaic River Basin upstream of the Great Falls in Paterson. PVSC's main interceptor sewer begins at Prospect Street in Paterson and generally follows the alignment of the Passaic River to the PVSC WRRF in the City of Newark.

PVSC does not own or operate any of the combined sewer overflow outfalls but has assumed a lead role in the development of the System Characterization and Landside Modeling Program on behalf of these permittees. The extent of the PVSC Service District and the combined sewer areas within the study area are illustrated in **Figure A-1** .

Eight of the municipalities within the PVSC District have combined sewer systems (CSSs) and have received authorization to discharge under their respective New Jersey Pollutant Discharge Elimination System (NJPDES) Permits for Combined Sewer Management. The eight PVSC CSO Permittees are listed below:

- Paterson City
- Newark City
- Kearny Town
- Harrison Town
- East Newark Borough
- City of Bayonne (Bayonne MUA was dissolved in 2016 and the City of Bayonne now own its CSS)
- Jersey City Municipal Utilities Authority (MUA)
- North Bergen MUA

A general schematic of the PVSC sewer system is included in **Figure A-2** .

Jersey City MUA is included in the list above, however it will submit its own System Characterization report separately. Any mention in this report of the infrastructure owned and operated (in part or in full) by Jersey City MUA is due to its hydraulic connection to the PVSC Water Resources Recovery Facility (WRRF) and is only included where it is necessary in order to properly characterize the PVSC system.

North Bergen Township has two combined sewer areas that are owned and operated by the North Bergen Township Municipal Utilities Authority (NBMUA) under two separate NJPDES permits; NBMUA and NBMUA (Woodcliff). The Woodcliff STP service area is separate from the PVSC service area and is covered in a separate System Characterization Report. Any mention in this

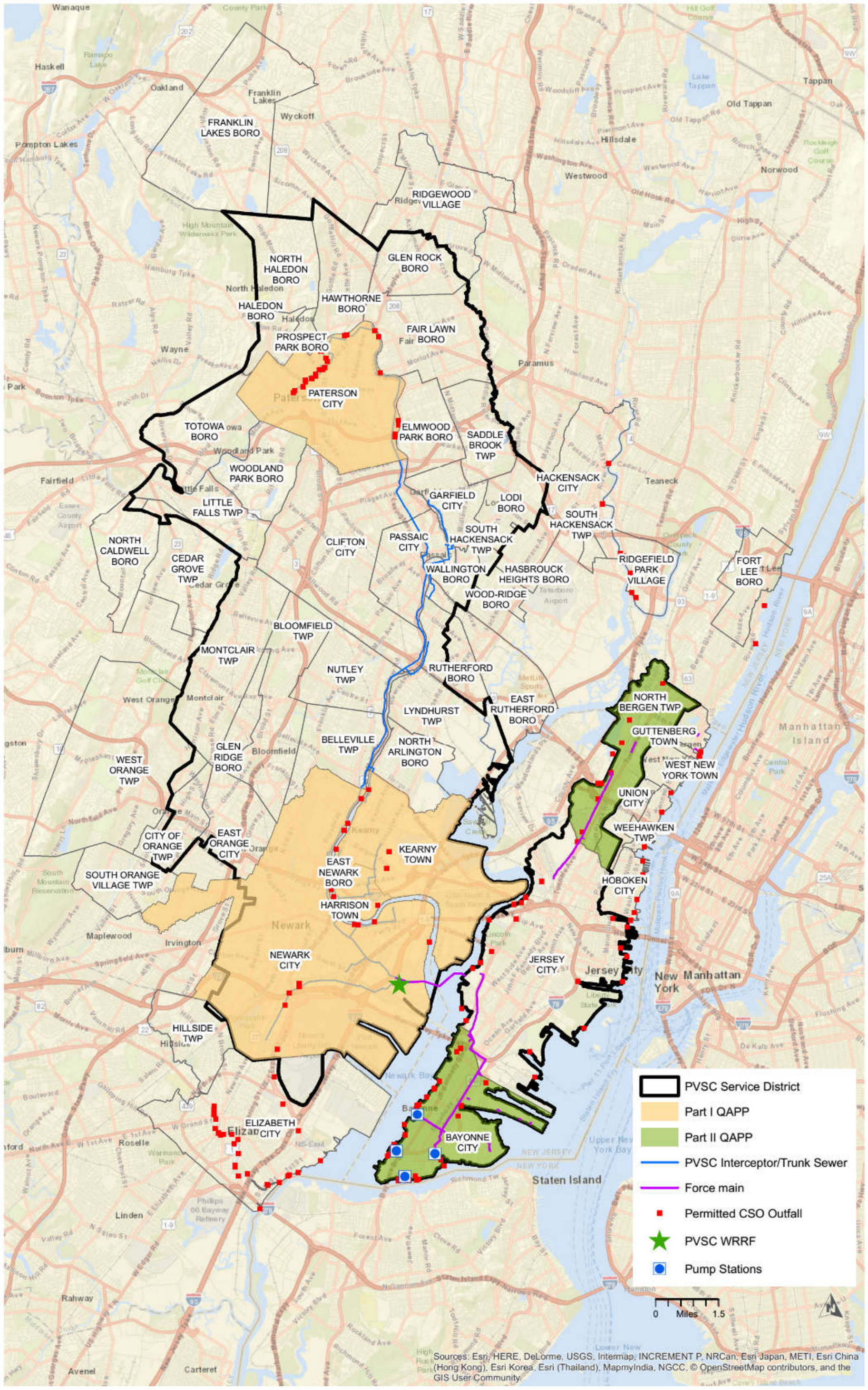

Figure A-1: The PVSC Service District[1]

[1] QAPP listed in above legend refers to the "System Characterization and Landside Modeling Program Quality Assurance Project Plan (QAPP)," which have been previously approved by NJDEP.

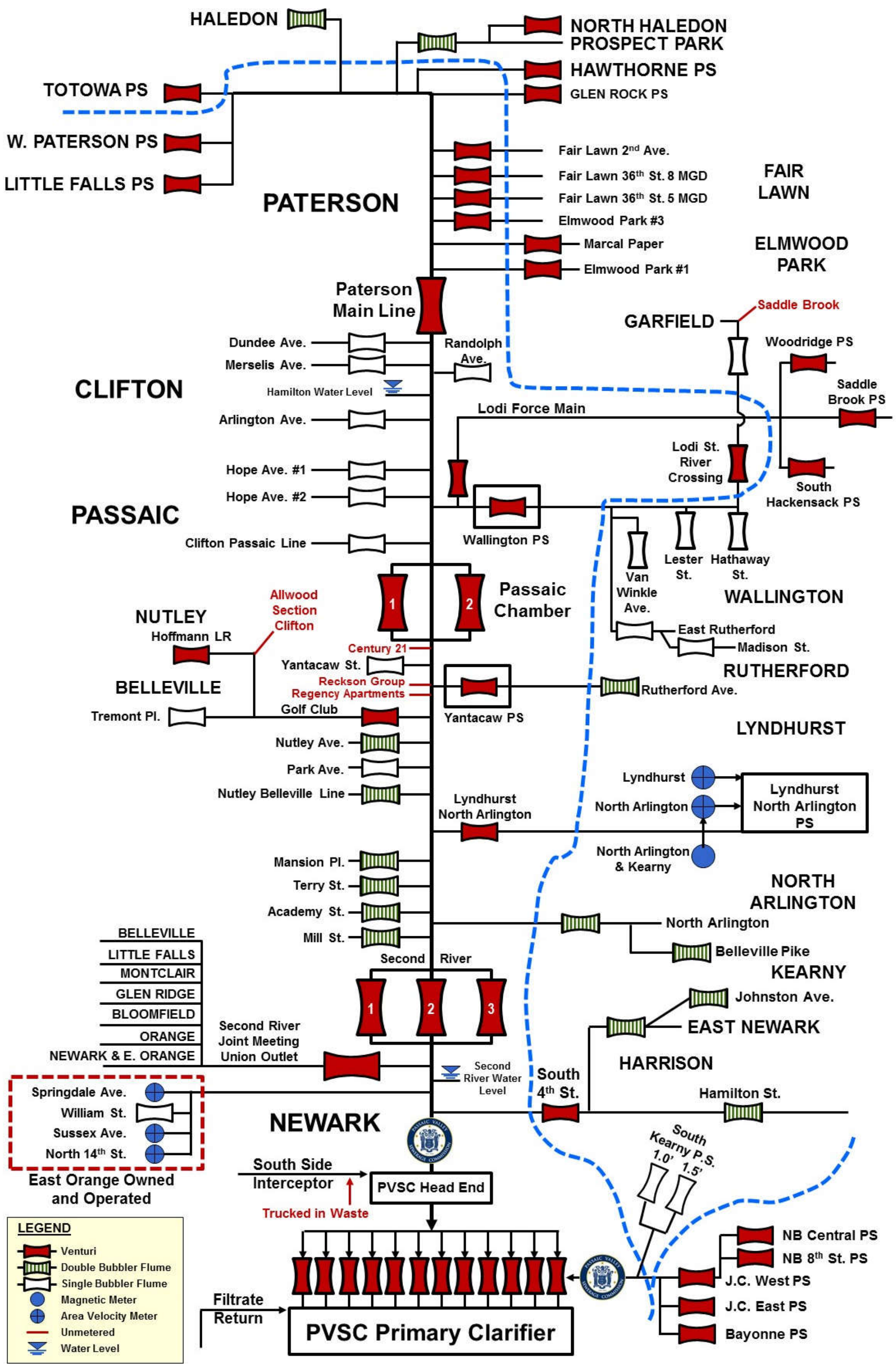

Figure A-2: The PVSC Sewer System Schematic

report of the infrastructure owned and operated (in part or in full) by North Bergen MUA (Woodcliff) is only included where it is necessary in order to properly characterize the North Bergen MUA system.

Permit Requirements

The NJPDES permits issued to PVSC and each CSO Permittee include requirements for PVSC and the CSO Permittees to cooperatively develop a CSO Long Term Control Plan (LTCP). To facilitate the CSO LTCP development, PVSC has undertaken the development of the System Characterization Report on behalf of these permittees.

Historical Characterization Reports

Between 1998 and 2003, PVSC conducted a Combined Sewer Overflow Discharge Characterization Study for all regulators and interceptor sewers owned and operated by the PVSC. This study was prepared by PVSC on behalf of the Borough of East Newark, the Towns of Harrison and Kearny and the City of Paterson. Jersey City, North Bergen MUA, and the Cities of Newark and Bayonne prepared their own separate reports in response to these NJPDES General Permit requirements. The following four reports were developed under this study:

- *Rainfall Monitoring Study Report* (December 1998): This study was conducted to develop an understanding of the rainfall characteristics in the combined communities in the PVSC service area, develop a correlation between rainfall characteristics and frequency of occurrence that causes a discharge, and develop rainfall monitoring for use in monitoring and modeling of CSO drainage basins.
- *CSO Monitoring Report* (December 1998): This effort was intended to quantify and qualify dry weather and wet weather wastewater flow and pollutant concentration variations at key CSO drainage basins so that this information can be used to calibrate and verify hydrologic and hydraulic models of the CSSs for the combined communities within the PVSC service area.
- *CSO Characterization Study Modeling Report* (December 2003): This study developed a refined US EPA approved Storm Water Management Model of the PVSC interceptor sewer system and tributary collections systems. This report presents the data collection efforts, describes the model, discusses characterization of CSOs and presents an approach for estimating pollutant loads from drainage areas that were not monitored within the study area.
- *Combined Sewer System Modeling Study* (February 2004): This study succeeded the 2003 Characterization and was intended to calibrate and verify the combined sewer overflow model to represent the response of the PVSC combined sewer system to historical precipitation events using a US EPA approved Storm Water Management Model.

Between 2003 and 2007, the Bayonne MUA and North Bergen MUA conducted individual Combined Sewer Overflow Discharge Characterization Studies for all regulators and interceptor sewers owned and operated within their respective systems. The reports were developed under the following studies:

City of Bayonne

- *CSO Characterization Study Final Modeling Report Volumes I and II (November 2005);* Bayonne performed continuous rainfall monitoring; long-term flow monitoring at 8 stations both in-stream and at outfalls; and performed dry and wet weather monitoring and overflow water quality sampling at 3 locations. This effort informed the current sampling and modeling program effort by providing suitable locations to characterize the Bayonne system and will aid in calibration and verification of previously developed SWMM models of each Bayonne CSO drainage basin. It will also provide a baseline to compare dry and wet weather quality and quantity as well as a comparison of CSO flows and pollutant concentrations/loadings since the 2005 study.
- *CSO Discharge Characterization Study - Rainfall Monitoring Study Report (August 2006);*
  Bayonne conducted its rainfall monitoring program to develop an understanding of the rainfall characteristics of its service area, determine any correlation between rainfall characteristics and frequency of occurrence of CSO discharges, and establish a rainfall monitoring network. This information will supplement other rainfall data collected in as part of this characterization study to correlate the hydraulic and hydrologic response to rainfall of the combined sewer system.

North Bergen Municipal Utilities Authority

- *CSO Characterization Study Group 2 Dry Weather Quality and Quantity Monitoring Report (June 2003);*
- *CSO Characterization Study Water Quality and Quantity Monitoring Report (March 2005)*

These studies developed background information on the combined sewer systems tributary to each regulator as well as the analysis of historical rainfall patterns, overflow volumes and pollutants contained in the CSO discharges. The information collected and the modeling tools developed under these previous studies were supplemented and updated as part of the System Characterization and Landside Modeling Program Quality Assurance Project Plan (QAPP). Each section of the QAPP summarized the data collected under previous studies (performed under past QAPPs) and outlined the supplemental data collected under the most recent QAPP. Baseline Compliance Monitoring and Receiving Water Quality Modeling of the receiving waters were also addressed under separate QAPPs.

A.6 PURPOSE OF REPORT

Section D.3.b.i of the NJPDES permit indicates that as part of the LTCP requirements a System Characterization Work Plan must be completed and submitted to the NJDEP 6 months from the effective date of the permit. To meet this requirement, two System Characterization and Landside Modeling Program QAPPs were submitted for all eight CSO Permittees and PVSC to be executed and performed by the PVSC. See **Table A-1** for each Municipality and associated QAPP. The System Characterization and Landside Modeling Program includes the rainfall monitoring, wastewater sampling, collections system monitoring, modeling and other work necessary to characterize the CSO discharges from the participating municipalities and for development of a collections system model for the purposes of evaluating CSO control alternatives and developing a CSO LTCP.

Table A-1: Municipality and associated QAPP submissions

Municipalities and Permittees	QAPP Submission
PVSC; East Newark Borough; Town of Harrison; Town of Kearny; City of Newark; City of Paterson	PVSC QAPP Part 1
Bayonne City; Jersey City MUA; North Bergen MUA	PVSC QAPP Part 2

NOTE: NBMUA (Woodcliff) and Guttenberg was included under separate QAPP.

In accordance with the PVSC and the eight CSO Permittee NJPDES Permits' LTCP requirements, a System Characterization Report shall be submitted by July 1, 2018. This System Characterization Report (SCR) has been developed to meet these permit requirements and incorporates the results of the Quality Assurance Project Plans (QAPPs) for the System Characterization and Landside Modeling Program, a summary of the Baseline Monitoring and Modeling Plan program, and the System Characterization mapping of the combined and separate sewer areas within the PVSC CSO Service District. Details of the Baseline Compliance Monitoring Program will be submitted under a separate Report. This System Characterization Report constitutes the PVSC CSO District Service Area *System Characterization Report* (SCR) developed on behalf of the following CSO Permittees:

- Paterson City
- Newark City
- Kearny Town
- Harrison Town
- East Newark Borough
- Bayonne City
- North Bergen MUA

Section G.1 of the PVSC NJPDES Permit Number NJ0021016 outlines the requirements of the System Characterization Monitoring and Modeling of the Combined Sewer system study that will provide a comprehensive characterization of the CSS.

The objective of the SCR is to provide NJDEP, PVSC, and the municipalities with a comprehensive and empirical understanding of the physical nature and hydraulic performance of their respective sewerage systems for use in optimizing the performance of the current systems and in the development of CSO control alternatives

A.7 SUMMARY OF WORK PLANS/QAPP

In accordance with consultation with NJDEP as NJPDES permitting authority, the following QAPPs have been developed for PVSC to meet the permitting requirements to cover sampling and analysis of the stormwater, wastewater and receiving water of the service area.

1. **System Characterization and Landside Modeling Program QAPP,** which includes wastewater collection system sampling and analysis as well as landside modeling. The System Characterization and Landside Modeling Program QAPP outlines the program necessary to address this requirement of the Permit. **The results of the System Characterization Wastewater Collection System Sampling and analysis program are included in this System Characterization Report.**

2. **Baseline Compliance Monitoring QAPP,** which includes sampling and analysis of the receiving waters. **The results of the sampling and analysis of the Baseline Compliance Monitoring of the Receiving Waters will be included under a separate report; the *Compliance Monitoring Program Report.***

3. **Pathogen Water Quality Modeling QAPP;** which includes the computational model of the receiving waters **(Not a permit requirement).**

The project goals and objectives for the System Characterization and Landside Modeling Program included:

- Supplement and update, as appropriate, the site specific dry and wet weather data to be used to recalibrate and verify the InfoWorks collections system model of those collections systems tributary to the PVSC WRRF.
- Define the CSSs' hydraulic response to rainfall.
- Supplement the existing dry weather water quality and quantity data to be used in the representation of each CSO drainage basin.
- Determine the CSO flows and pathogen concentrations/loadings being discharged to the receiving streams as a result of varied rainfall events.
- Supplement the stormwater quality data for various land use applications.

PVSC and the eight CSO Permittees developed a monitoring program that collected dry and wet weather data that was used to calibrate and verify a hydraulic model for CSO basin upstream of the PVSC WRRF. This data also defined the combined sewer system response to rainfall and determined the quality and quantity of dry weather flow in the system as well as determine CSO flow quantities and pollutant concentrations/loadings discharged to receiving streams.

The purpose of the monitoring program was to quantify and qualify dry weather and wet weather wastewater flow and pathogen concentration variations at key CSO and stormwater drainage basins to calibrate and verify hydrologic and hydraulic models (InfoWorks) of the CSSs within the Borough of East Newark, the Township of North Bergen, Towns of Harrison and Kearny, and the Cities of Bayonne, Newark and Paterson. This work was used to update the mathematical tool (sewer system model) used to assess residual storage and maximum hydraulic conveyance capacity in the PVSC, Bayonne and North Bergen interceptor system, pathogen concentrations and loading distributions during storm events and among CSO discharge points, calculate pathogen loads from CSOs and stormwater to the receiving water, and for the development and evaluation of long term control alternatives and/or modifications to the water quality standards (WQS) during wet weather events.

Data collected under the QAPPs was used to supplement the data from the 2003 CSO Characterization Study Modeling Report and the February 2004 CSO Modeling Study. The flow metering and CSO laboratory analytics were utilized in performing the following LTCP development tasks:

- Rainfall-Overflow Correlation Analysis
- Rainfall Event Characterization
- Collection System Model Validation
- Characterization of Sanitary, Stormwater and CSO Wastewater Quality

Wastewater quality sampling and flow metering were conducted in order to characterize the CSO quantity and quality for each of the combined sewer drainage areas. The characterization of the CSOs included determination of relationships between rainfall, runoff/overflow volume and pathogen loads. The data obtained was used in the validation of the InfoWorks Collections System Model for all the combined sewer drainage basins tributary to the PVSC control facilities, main interceptor sewer and force mains.

A.7.1 Receiving Waters Description

The receiving waters include the receiving waterbody of the combined sewer service area of the PVSC Sewer District and expand from this service area to include all receiving and adjacent downstream waters that may be potentially affected by CSOs from the various combined sewer service areas of the NJ CSO Group. Impacted waters include the Passaic River, Hackensack River, Newark Bay, Hudson River, Kill Van Kull, Arthur Kill, Raritan River and Raritan Bay, as well as their tributaries.

A.8 CONTENTS OF THIS REPORT

This report provides a comprehensive characterization of the CSS developed through records review, monitoring, modeling establishing the existing baseline conditions to evaluate the efficacy of the CSO technology based controls, and determine the baseline conditions upon which the LTCP will be based.

PVSC and the municipal permittees have developed a thorough understanding of their respective sewerage systems, the systems' responses to precipitation events of varying duration and intensity, the characteristics of system overflows, and water quality issues associated with combined sewer overflows (CSOs) emanating from the systems and is presented in this report.

An overview of the organization and contents of this system characterization report are provided on **Table A-2**.

Table A-2: System Characterization Report Contents and Organization

Section		Topics Covered
A	Introduction and Background	Documents the problem definition, background, project description, summary and table of contents.
B	Regulatory Requirements	Describes the scope, purpose and regulatory context of the System Characterization Report.
C	Overview of Wastewater Facilities and Service Area	Characterizes the service area comprising the PVSC combined sewered municipalities that are the subject of this system characterization report and current wastewater treatment facilities within the service area.
D	Characteristics of the Combined Sewer System	Characterizes the municipal collection sewers, sewer mains, interceptors and appurtenances such as pump stations, existing CSO control facilities, regulator structures, and CSO outfalls.
E	Collection of Precipitation and Sewer Flow Monitoring	Documents the precipitation and flow monitoring programs, data analyses, integration of wastewater treatment plant operational data, data validation and QA/QC and presents the results of the analyses.
F	Characteristics of the Receiving Waters	Describes the watersheds, physical characteristics, and hydrodynamics of the receiving streams. Also describes the designated uses and current water quality compliance (e.g. 303(d) listings) and achievement of designated use status.
G	Collection of Water Quality Data	Documents the regulatory requirements for water quality data collection, historic water quality data collection, the water quality monitoring program and related QAPP and receiving water quality results.
H	Typical Hydrologic Period	Documents the requirements for and selection of the typical year and summarizes the hydrologic characteristics of the typical year.
I	Hydrologic and Hydraulic Modeling	Documents the development and scope of the H&H model used in this system characterization and to be used in the development of CSO control alternatives. The documentation includes model inputs, sensitivity analyses, model calibration and validation and modeling results.
J	References	
K	Abbreviations	

SECTION B - REGULATORY REQUIREMENTS

B.1 INTRODUCTION

This document constitutes the PVSC SCR developed by PVSC on behalf of the municipalities and municipal authorities served by PVSC that are listed below in **Table B-1**. The SCR provides a "Characterization Monitoring and Modeling of the Combined Sewer System" under Part IV Section G.1 of the municipalities' respective New Jersey Pollutant Discharge Elimination System (NJPDES) permit.

Table B-1: Permittees Covered Under this System Characterization Report

Municipality	NJPDES #
PVSC	NJ0021016
Borough of East Newark	NJ0021016
Town of Harrison	NJ0108871
Town of Kearny	NJ0111244
City of Newark	NJ0108758
City of Paterson	NJ0108880
City of Bayonne	NJ0209240
North Bergen MUA	NJ0108898

B.2 REGULATORY CONTEXT

B.2.1 NJPDES Permit Requirements

Under Section 402 of the CWA, all point source discharges to the waters of the United States must be permitted. USEPA Region II has delegated permitting authority in New Jersey to the New Jersey Department of Environmental Protection (NJDEP). The permits are reissued on a nominal five-year cycle. All twenty-one New Jersey municipalities and municipal authorities with CSSs were issued new permits in 2015 that set forth requirements for the completion of the system characterization and the development of LTCPs on the following schedule:

- System Characterization Work Plan (QAPP) must be completed and submitted to the NJDEP 6 months from the effective date of the permit – January 1, 2016
- Submittal of the System Characterization Report to NJDEP - July 1, 2018;
- (LTCP Report 1) Development & Evaluation of CSO Control Alternatives - July 1, 2019; and
- (LTCP Report 2) Selection and Implementation of Alternatives - July 2020.

The System Characterization Reports are to be updates to and to utilize where applicable, previous system inventories and evaluations such as the *Sewage Infrastructure Improvement Act Planning Studies* conducted in the late 1990s. The municipalities documented their implementation of the nine minimum controls under an earlier NJPDES permit cycle.
With minor exceptions such as lists of applicable previous studies, the 2015 permits are standardized. The 2015 major elements to be included in the System Characterization Report are outlined in Part IV (Specific Requirement: Narrative) paragraphs G.1.d.i through G.1.d.v. of the

permits. These requirements are reproduced on **Table B-2** along with the section of this SCR in which the requirements are addressed.

Table B-2: Review of Major Elements of the System Characterization Report

Permit Section	Permit Requirement	SCR Section
Part IV G.1.a	"The permittee, as per D.3.a and G.10, shall submit an updated characterization study that will result in a comprehensive characterization of the CSS developed through records review, monitoring, modeling and other means as appropriate to establish the existing baseline conditions, evaluate the efficacy of the CSO technology based controls, and determine the baseline conditions upon which the LTCP will be based. The permittee shall work in coordination with the combined sewer communities for appropriate Characterization, Monitoring and Modeling of the Sewer System."	Entire SCR
Part IV G.1.b	"The characterization shall include a thorough review of the entire collection system that conveys flows to the treatment works including areas of sewage overflows, including to basements, streets and other public and private areas, to adequately address the response of the CSS to various precipitation events"	Section C: ***Overview of Wastewater Treatment Facilities and Service Areas***
		Section D: ***Characteristics of the Combined Sewer System***
	"The characterization shall identify the number, location, frequency and characteristics of CSOs"	Section I ***Hydrologic and Hydraulic Modeling***
	"The characterization shall identify water quality impacts that result from CSOs"	Section G: ***Collection of Water Quality Data***
		Section F: ***Characteristics of the Receiving Waters***
Part IV G.1.c	"The permittee may use previous studies to the extent that they are accurate and representative of a properly operated and maintained sewer system and of the currently required information"	Applicable data from the cited references have been utilized throughout the appropriated sections of this SCR.

Permit Section	Permit Requirement	SCR Section
Part IV G.1.d.i	Rainfall Records Analysis	Section E: ***Collection of Precipitation and Sewer Flow Monitoring***
		Section H: **Typical Hydrologic Period**
Part IV G.1.d.ii	Combined Sewer System Characterization	Section D: ***Characterization of the Combined Sewer System***
Part IV G.1.d.iii	CSO Monitoring	
Part IV G.1.d.iv	System Hydrologic & Hydraulic Modeling	Section I: ***Hydrologic & Hydraulic Modeling***
Part IV G.1.d.v	The permittee shall identify sensitive areas where CSOs occur	Section F: **Characteristics of Receiving Waters**

B.2.2 USEPA's CSO Control Policy

USEPA's CSO Control Policy (Policy) was issued in April of 1994[2] to elaborate on the 1989 National CSO Control Strategy and to expedite compliance with the requirements of the Clean Water Act (CWA). The Policy provided guidance to municipal permittees with CSOs, to the state agencies issuing National Pollution Discharge Elimination permits (e.g. NJDEP and NJPDES permits) and to state and interstate water quality standards authorities (e.g. the Interstate Environmental Commission).[3] The Policy establishes a framework for the coordination, planning, selection and implementation of CSO controls required for permittee compliance with the Clean Water Act (CWA).

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2 59 FR 18688 et seq.

3 The Interstate Environmental Commission (IEC) is a tri-state air and water pollution control agency—that is, a joint agency—serving the states of New York, New Jersey, and Connecticut.

The Policy includes three major activities required of municipalities with CSO related permits:

- ***System Characterization*** – The identification of current combined sewer system assets and current performance characteristics;
- ***Implementation of the Nine Minimum Controls***[4] – identified in the Policy to ensure that the current combined sewer system is being optimized and property maintained; and
- ***Development of a Long-Term Control Plan (LTCP)*** – The analysis and selection of long term capital and institutional improvements to the combined sewer system that once fully implemented will result in compliance with the CWA.

The Policy includes provisions for public and stakeholder involvement (e.g. the CSO Supplemental Committees), the assessment of affordability (rate-payer impacts) and financial capability (permittee ability to finance the long-term controls) as a driver of implementation schedules and two CSO control alternatives. The "presumption" approach is premised on the presumption that the achievement of certain performance standards, e.g. no more than an average of four overflow events per year; or the elimination or capture of at least 85% by volume of the combined sewage collected in the CSS during precipitation events; or the elimination or removal of no less than the mass of the pollutants for the volumes that would be eliminated or captured, would result in CWA compliance subject to post-implementation verification. Under the "demonstration" approach, permittees demonstrate that their proposed controls do not preclude the attainment of water quality standards.

The Policy includes regulations for the collection of water quality data required of municipalities with CSO related permits. Section II.C.1 of the CSO Control Policy "Characterization, Monitoring and Modeling of the Combined Sewer System" states:

> *"In order to design a CSO control plan to adequately meet the requirements of the CWA, a permittee should have a thorough understanding of its sewer system, the response of the system to various precipitation events, the characteristics of the overflows, and the water quality impacts that result from CSOs. The permittee should adequately characterize through monitoring, modeling, and other means as appropriate, for a range of storm events, the response of its sewer system to wet weather events including the number, location and frequency of CSOs volume, concentration and mass of pollutants discharged and the impacts of the CSOs on the receiving waters and their designated uses."*

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4 The nine minimum controls include: 1) proper operation and regular maintenance; 2) maximizing the use of the collection system for storage where feasible; 3) review and modification of the Industrial Pretreatment Program to minimize CSO impacts; 4) maximization of flow to the wastewater treatment plant; 5) the prohibition of CSOs during dry weather; 6) control of solids and floatables (addressed by NJDEP's requirement of screening or other facilities in the late 2000s); 7) pollution prevention; 8) public notification; and 9) monitoring CSO impacts and controls. 59 FR 18691.

The CSO Control Policy states that the major elements of a sewer system characterization include:

Rainfall Records

> *"The permittee should examine the complete rainfall record for the geographic area of its existing CSS using sound statistical procedures and best available data. The permittee should evaluate flow variations in the receiving water body to correlate between CSOs and receiving water conditions."*

Combined Sewer System Characterization

> *"The permittee should evaluate the nature and extent of its sewer system through evaluation of available sewer system records, field inspections and other activities necessary to understand the number, location and frequency of overflows and their location relative to sensitive areas and to pollution sources in the collection system, such as indirect significant industrial users."*

CSO Monitoring

> *"The permittee should develop a comprehensive, representative monitoring program that measures the frequency, duration, flow rate, volume and pollutant concentration of CSO discharges and assesses the impact of the CSOs on the receiving waters."*

Modeling

> *"Modeling of a sewer system is recognized as a valuable tool for predicting sewer system response to various wet weather events and assessing water quality impacts when evaluating different control strategies and alternatives. EPA supports the proper and effective use of models, where appropriate, in the evaluation of the nine minimum controls and the development of the long-term CSO control plan."*

B.2.3 USEPA CSO Guidelines

The data collection, analyses and this characterization report were written and conducted in conformance with the applicable USEPA guidance documents as shown in **Table B-3**.

Table B-3: USEPA Guidance Documents Used in the Preparation of the System Characterization Report

	Title	Date	Document Number
1	Combined Sewer Overflows Guidance for Long-Term Control Plan	1995	EPA 832-B-95-002
2	Combined Sewer Overflows Guidance for Screening and Ranking	1995	EPA 832-B-95-004
3	CSO Post Construction Compliance Monitoring Guidance	2011	EPA-833-K-001

	Title	Date	Document Number
4	Guidance for Quality Assurance Project Plans	2002	EPA/240/R-02/009
5	Guidance: Coordinating CSO Long-Term Planning with Water Quality Standards Reviews	2001	EPA-833-R-01-002
6	Manual: Combined Sewer Overflow Control	1993	EPA/625/R-83-007
7	NPDES Permit Writer's Manual	2010	EPA-833-K-10-001
8	Sewer System Infrastructure Analysis & Rehabilitation	1991	EPA/625/6-91-030
9	Water Quality Standards Handbook: Second Edition	1994	EPA 823-B-94-005
10	Water Quality Standards Handbook: Second Edition	2007	

B.2.4 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

Section 303(d) of the federal Clean Water Act or "CWA" (33 USC § 1251 et seq.) requires each state to identify those waters for which effluent limitations are not stringent enough to attain applicable water quality standards; establish a priority ranking for such waters based on extent of water quality impairment and designated use non-support; establish a total maximum daily load (TMDL) for each pollutant causing water quality impairment, based on their priority ranking, at a level necessary to attain applicable water quality standards; and submit a list to USEPA of all impaired waters and their pollutant causes (i.e., the 303(d) List).

The New Jersey Department of Environmental Protection (NJDEP) has established the 2014 New Jersey Integrated Water Quality Assessment Report. The primary source of information regarding causes of impairment, and the Total Maximum Daily Load (TMDL) status of the water bodies (if any) is the 2014 New Jersey Integrated Water Quality Assessment Report, which satisfies New Jersey's requirement of both Section 303(d) and 305(b) of the Clean Water Act (CWA). The NJDEP Website explains the categories as shown in **Table B-4**.

Table B-4: Components of New Jersey's Integrated List of Water (Integrated List)

Sublist	Component
Sublist 1	An assessment unit is fully supporting all applicable designated uses and no uses are threatened. (The Department does not include the fish consumption use for determining placement on this sublist.)
Sublist 2	The assessment unit is fully supporting the designated use but is not supporting all applicable designated use(s).
Sublist 3	Insufficient data and information are available to determine if the designated use is fully supported.
Sublist 4	One or more designated uses are not supported or are threatened but TMDL development is not required because of one of the following reasons:

Sublist	Component
Sublist 4A	A TMDL has been completed for the parameter causing designated use non-support.
Sublist 4B	Other enforceable pollutant control measures are reasonably expected to result in fully supporting the designated use in the near future.
Sublist 4C	Non-support of the designated use is caused by something other than a pollutant.
Sublist 5	One or more designated uses are not supported or are threatened by a pollutant(s) that requires development of a TMDL.
Sublist 5A	Arsenic does not attain standards, but concentration are below those demonstrated to be from naturally occurring conditions.
Sublist 5L	Designated use impairment is caused by a "legacy" pollutant that is no longer actively discharged by a point source.
Sublist 5R	Water quality impairment is not effectively addressed by a TMDL, such as nonpoint source pollution that will be controlled under an approved watershed restoration plan or 319(h) Watershed Based Plan.

The Sublist 5 list constitutes the Section 303(d) list that the USEPA will approve or disapprove under the CWA. For the purposes of the determination of Pollutants of Concern, Sublists 4A and 5 are the relevant categories as they indicate the need for a TMDL in the receiving water body and the limiting of additional loadings for those parameters.

B.2.5 Interstate Environmental Commission Requirements

With the exception of the City of Paterson, the municipalities and authorities covered by this System Characterization Report fall within the jurisdiction of the Interstate Environmental Commission (IEC). The Interstate Environmental Commission (IEC) is a tri-state air and water pollution control agency serving the states of New York, New Jersey, and Connecticut. The Commission and its area of jurisdiction were established in 1936 under a instate compact, with the consent of Congress. The IEC establishes the receiving stream water quality standards to which NJPDES permittees are subject under the federal Clean Water Act[5] and the New Jersey Water Pollution Control Act.[6]
The IEC has specified two classes of waters:[7]

Class A Waters - Class A waters are suitable for all forms of primary and secondary contact recreation and for fish propagation, including shellfish harvesting in designated areas. There are no Class A waters within the receiving waters of the PVSC combined sewered municipalities.

Class B Waters – IEC identified two sub-classes:

- **Class B-1** – the IEC water quality standards specify that Class B-1 waters remain "Suitable for fishing and secondary contact recreation. They shall be suitable for the

5 33 U.S.C. Chapter 26
6 N.J.S.A 58:10A-1 et seq.
7 Source: IEC website: http://www.iec-nynjct.org/wq.regulations.htm

growth and maintenance of fish life and other forms of marine life naturally occurring therein, but may not be suitable for fish propagation."

- **Class B-2** – the IEC water quality standards specify that Class B-2 waters remain: "Suitable for passage of anadromous fish and for the maintenance of fish life in a manner consistent with the criteria established by the general regulations."

The IEC water quality standard classification zones applicable to the PVSC combined sewered municipalities are shown on **Figure B-1**.

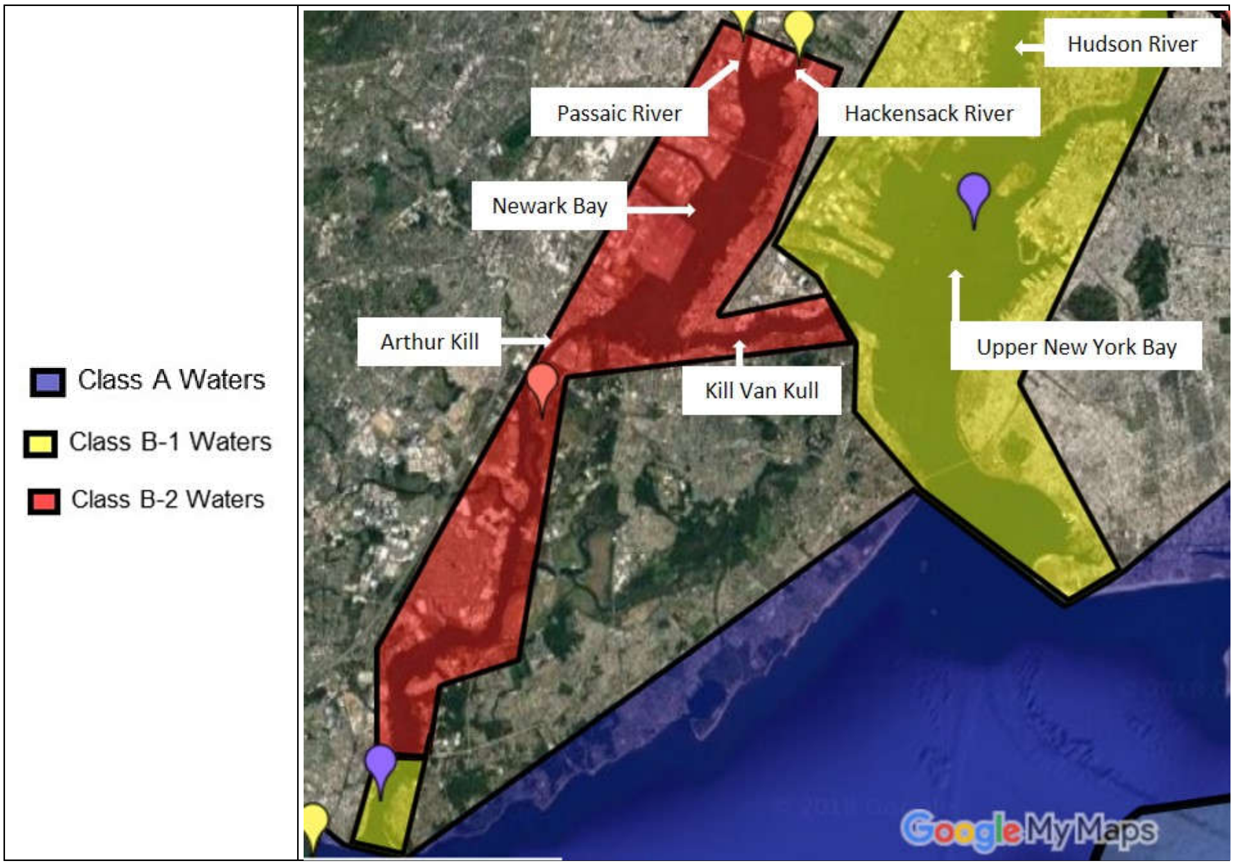


Figure B-1: Interstate Environmental Commission Water Quality Classifications

As shown on **Figure B-1**, the mouth of the Passaic River, the mouth of the Hackensack River, Newark Bay and the Kill Van Kull are classified as B-2 waters and the Upper Bay (Hudson River) is classified as B-1. Water quality standards applicable to Class B-1 and Class B-2 waters relevant to CSO discharges are provided in **Table B-5** below.

Table B-5: IEC Water Quality Standards for IEC Class B Waters

Water Quality Parameter	Value
Dissolved Oxygen	
Class B-1	≥ 4 milligrams per liter
Class B-2	≥ 5 milligrams per liter
Classes B-1 & B-2	Further, all sewage or other polluting matter discharged or permitted to flow into waters of the District shall first have been so treated as to effect a reduction in the oxygen demand of the effluent sufficient to maintain the applicable dissolved oxygen requirement in the waters of the District and also maintain the dissolved oxygen content in the general vicinity of the point of discharge of the sewage or other polluting matter into those waters, at a depth of about five feet below the surface.
Fecal Coliform (effluent discharges)	• 200 per 100 ml on a 30 consecutive day geometric average; • 400 per 100 ml on a 7 consecutive day geometric average; • 800 per 100 ml on a 6 consecutive hour geometric average; and • no sample may contain more than 2400 per 100 ml.
General Requirements	
• All waters of the Interstate Environmental District (whether of Class A, Class B, or any subclass thereof) shall be of such quality and condition that they will be free from floating solids, settleable solids, oil, grease, sludge deposits, color or turbidity to the extent that none of the foregoing shall be noticeable in the water or deposited along the shore or on aquatic substrata in quantities detrimental to the natural biota; nor shall any of the foregoing be present in quantities that would render the waters in question unsuitable for use in accordance with their respective classifications.	
• No toxic or deleterious substances shall be present, either alone or in combination with other substances, in such concentrations as to be detrimental to fish or inhibit their natural migration or that will be offensive to humans or which would produce offensive tastes or odors or be unhealthful in biota used for human consumption.	
• No sewage or other polluting matters shall be discharged, permitted to flow into, be placed in, or permitted to fall or move into the waters of the District, except in conformity with these regulations.	

The IEC website states:

> *"An effluent discharge which does not satisfy the requirements of the Commission shall not be considered to be in violation thereof if caused by temporary excess flows due to storm water conveyed to treatment plants through combined sewer systems, provided that the discharger is operating the facility with reasonable care, maintenance, and efficiency and has acted and continues to act with due diligence and speed to correct the condition resulting from the storm water flow.*

Unless there has been rainfall in greater than trace amounts or significant melting of frozen precipitation during the immediately preceding 24 hours, no discharges to the waters of the Interstate Environmental District shall occur from combined sewer regulating devices."

Additional information relating to the applicable water quality standards and the current use attainment status of the receiving waters is provided in Section F of this report.

B.2.6 New Jersey Administrative Code

New Jersey Administrative Code (NJAC) Section 7:9B Surface Water Quality Standards lists the classifications, designated uses, and water quality criteria for all New Jersey water bodies. The classification and water quality standards for the CSO receiving waters within the PVSC CSO Sewer District are shown in **Table B-6** below.

Table B-6: The NJ Administrative Code Classifications of PVSC Sewer District CSO Receiving Waters

Waterbody	Reach	Classification
Passaic River	Paterson - Outlet of Osborn Pond to Dundee Lake dam	FW2-NT
	Little Falls - Dundee Lake dam to confluence with Second River	FW2-NT/SE2
	Newark (@ Second River)	SE3
Hackensack River	Kearny Point	SE3
Hudson River	Englewood Cliffs	SE2
Kill Van Kull	Kill Van Kull	SE3
Newark Bay	Newark Bay	SE3

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 ml)
FW2-NT (Fresh Water Non Trout)	1. Maintenance, migration and propagation of the natural and established biota; 2. Primary contact recreation; 3. Industrial and agricultural water supply; 4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation, and sedimentation, resulting in substantial particulate	E. Coli	126 GM, 235 SSM

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 ml)
	removal but no consistent removal of chemical constituents) and disinfection; and 5. Any other reasonable uses.		
SE2 (Saline Water)	1. Maintenance, migration and propagation of the natural and established biota; 2. Migration of diadromous fish; 3. Maintenance of wildlife; 4. Secondary contact recreation; and 5. Any other reasonable uses.	Fecal Coliform	770 GM
SE3 (Saline Water)	1. Secondary contact recreation; 2. Maintenance and migration of fish populations; 3. Migration of diadromous fish; 4. Maintenance of wildlife; 5. Any other reasonable uses.	Fecal Coliform	1500 GM

* *"The geometric mean shall be calculated using a minimum of five samples collected over a thirty-day period"*

A map showing the NJAC classifications for all of the waterbodies is found below as **Figure B-2**.

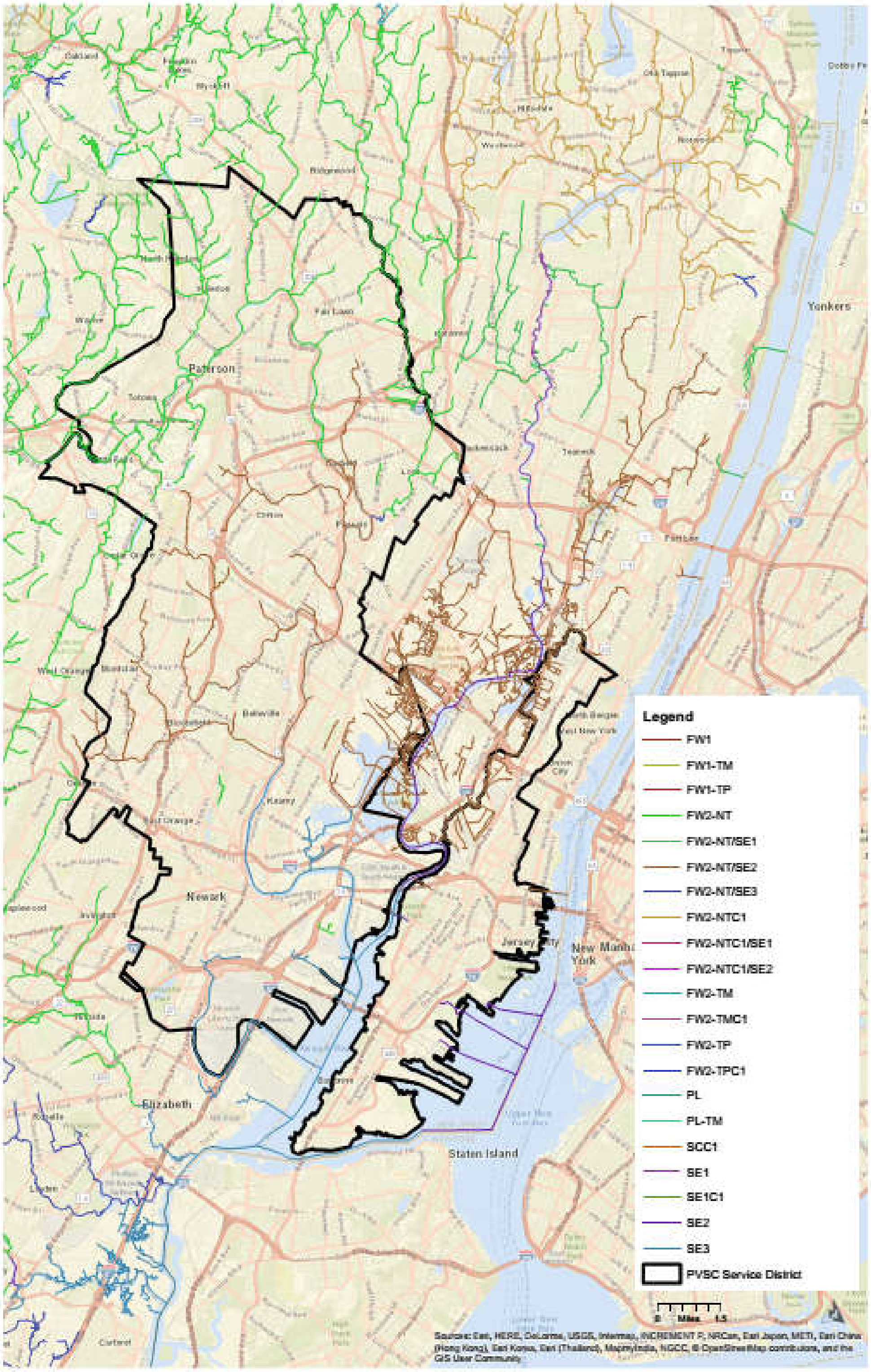


Figure B-2: NJAC Classifications of PVSC Sewer District Waterbodies

SECTION C - OVERVIEW OF WASTEWATER TREATMENT FACILITIES AND SERVICE AREAS

C.1 WASTEWATER TREATMENT FACILITIES

Passaic Valley Sewerage Commission

PVSC owns and operates a 330 million gallons per day (MGD) WRRF that covers approximately 142 acres and is located in an industrial area of Newark, NJ. A detailed schematic of the PVSC Service Area can be seen in **Figure C-1**.

The PVSC Facility receives flow from three sources: the Main Interceptor Sewer, the South Side Interceptor, and flow from Hudson County. The Main Interceptor is approximately 22 miles long and is routed from the City of Patterson in Passaic County to the WRRF in the City of Newark in Essex County, generally following the west bank of the Passaic River. The South Side Interceptor is approximately six (6) miles long and is located entirely within the City of Newark. The Main and South Side Interceptor's direct flow to the Headworks that includes a channelized Forebay that divides flow between six (6) grit channels. Wastewater is screened and degritted and moved through an effluent channel to the Influent Pumping Station. Flow is then lifted by six (6) Archimedes screw pumps to Primary Clarifiers. The Hudson County flow, which includes flow from the cities of Jersey City, Bayonne, North Bergen and South Kearny, enters the plant downstream of the Forebay just before the Primary Clarifiers. The combined flows then enter secondary treatment consisting of Aeration Tanks which utilize a pure oxygen activated sludge process and Final Clarifiers. Treated wastewater is disinfected with sodium hypochlorite as it enters the Effluent Pumping Station and is pumped to one of two outfalls. The main outfall discharges to Upper New York Bay, and flow in excess of the capacity of the main outfall flows to a chlorine contact tank prior to reaching the Newark Bay secondary outfall

Solids Treatment at the WRRF takes primary sludge from the Primary Clarifiers and Waste Sludge from the Aeration Tanks and transports them to gravity Sludge Thickeners. Thickened sludge then enters the Thickening Centrifuges to reduce its liquid volume. A wet-air oxidation process, known as Zimpro, conditions the sludge for dewatering before it is further reduced in volume in Decant Tanks. Sludge enters the final processing steps in filter presses and storage in cake silos prior to beneficial use.

North Bergen Municipal Utilities Authority

The North Bergen Township MUA owned and operated a small wastewater treatment plant called the Central Treatment Plant until its closure in October of 2010. The Central Treatment Plant was replaced with the Central Pump Station. The Township's wastewater from the original service area of the Central Treatment Plant, about 7 MGD, is now pumped to JCMUA's collection system for treatment at the PVSC WRRF. The remainder of the Township's wastewater that is generated outside of the service area of the Central Treatment Plant flows to the Woodcliff Sewage Treatment Plant (STP). The NBMUA also owns and operates the Woodcliff Sewage Treatment Plant (STP) and hold a separate NJPDES permitted for this plant discharge. The Woodcliff STP plant receives flow from the northeastern portion of North

Bergen service area, and from the Town of Guttenberg. Approximately 3 MGD is treated at the Woodcliff Sewage Treatment Plant (STP) in North Bergen and discharged into the Hudson River. Details regarding the NBMUA Woodcliff STP and its service area can be found in the report titled *Service Area System Characterization Report: NBMUA Woodcliff STP and Guttenberg (WCGB), dated June 2018.*

C.2 PVSC SEWER DISTRICT SERVICE AREA

The PVSC Sewer District service area is comprised of combined sewer areas and separate sewer areas that contribute flow to the PVSC WRRF. The combined sewer areas include several different municipalities who own and operate the CSSs and the combined sewer outfalls located within their jurisdiction. Separate sewer areas comprise the majority of the drainage area but only contributes approximately 40 percent of the flow to the PVSC WRRF. **Figure C-1** shows the municipalities and the type of sewer network they operate.

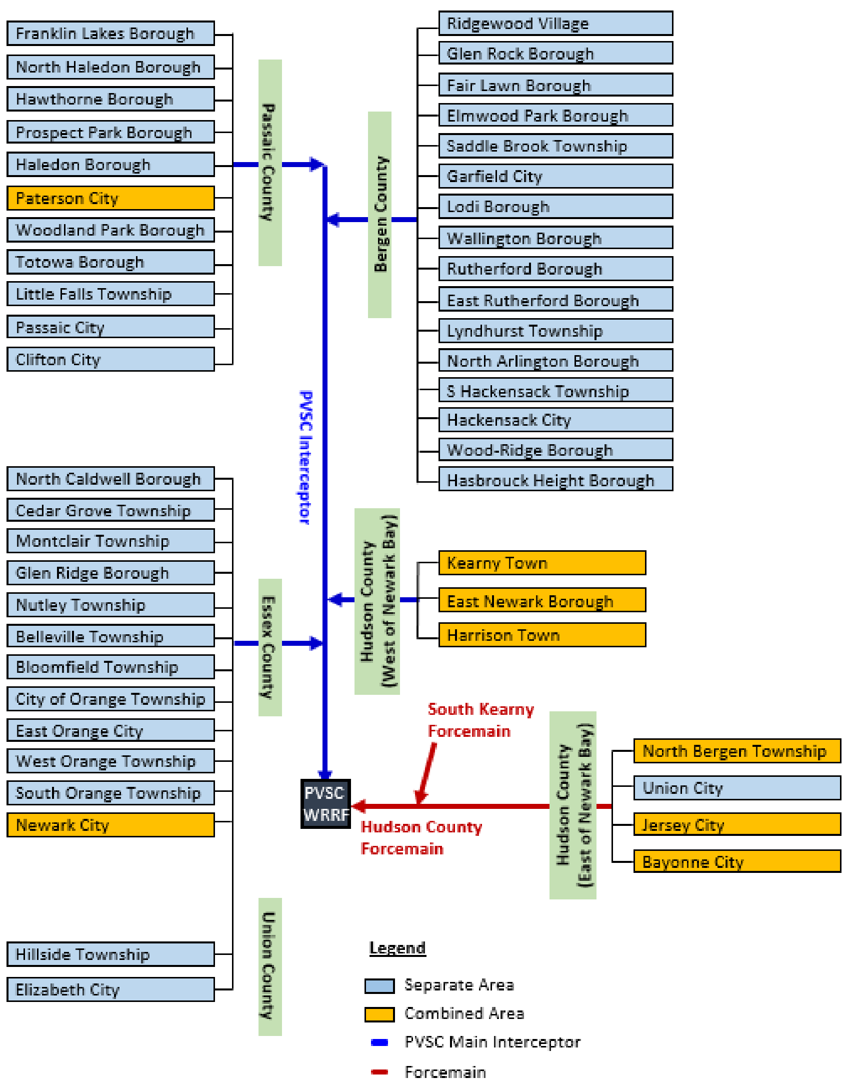


Figure C-1: PVSC Municipalities

C.2.1 Combined Sewer Service Area

Combined sewers, which serve eight of the municipalities within the PVSC Sewer District and collect surface runoff from the combined sewer service area. The total combined area is approximately 22,099 acres and makes up approximately 26 percent of the Total Contributing Area. The eight municipalities, their service area acreage and the number of CSO outfalls are listed in **Table C-1** below. All eight municipalities are authorized to discharge under their respective NJPDES Permits for Combined Sewer Management. PVSC does not own or operate any combined sewer outfalls. PVSC owns and operates CSO Facilities such as regulators, and netting facilities but the combined sewer outfalls are owned by other permittees.

Table C-1: Combined and Separate Sewer Service Area Municipalities

Municipality	Contributing area (acres)		Total Contributing Area (acres) [1]	Number of CSOs Located within Service Area
	Combined	Separate & Storm		
Bayonne City	1,706	36	1,742	28
East Newark Borough	62	0	62	1
Harrison Town [2]	423	354	771	6
Jersey City [3]	5,365		5,365	21
Kearny Town	1,243	2,763	4,006	5
Newark City	7,153	2,883	10,036	18
North Bergen MUA [4]	1,552	39	1,591	9
Paterson City	4,595	600	5,195	23
Subtotal	22,099	6,675	28,774	111
40 Separate Sanitary Communities		55,214	55,214	--
Total	22,099	61,889	83,988	111

Note:

1. The total acreage in the table above includes only the subcatchment areas in the model that contribute flow to the PVSC WRRF. The acreage does not include rivers, creeks or unsewered areas within a municipality.
2. Harrison's NJPDES permit currently includes 7 outfalls. NJDEP will be issuing Harrison a minor modification NJPDES permit action to remove Dey Street outfall 004A in the near future.
3. Jersey City will provide details of this information separately as part of its System Characterization Report.
4. NBMUA (Woodcliff) and Guttenberg will provide this information separately as part of its System Characterization Report.

The combined sewer municipalities on the east side of Newark Bay include the Cities of Jersey City and Bayonne, and the Township of North Bergen. These municipalities deliver their combined sewage through the Hudson County force main into the PVSC primary clarifiers at the PVSC WRRF. Two of the combined sewer municipalities, the Bayonne MUA and Jersey City MUA, own and operate their own CSSs, interceptors, CSO control facilities, and pumping stations. The City of Bayonne currently has a long term Agreement with a private operator for the Operation and Maintenance (O&M) of the CSS. Bayonne and Jersey City jointly own the force main used to transport wastewater from the CSO area east of the Newark Bay in Hudson County, to the primary clarifiers at the PVSC WRRF in Newark. PVSC does not own or operate any of the combined sewer overflow control or transportation facilities which service this section of the District.

North Bergen consists of two combined sewer areas, Central and Woodcliff area. North Bergen Township owns and operates the manholes and sewer systems in both of these areas. The North Bergen Municipal Utilities Authority (MUA) owns and operates the regulators, interceptors, outfalls, CSO facilities and the Woodcliff STP under two separate NJPDES permits; NBMUA and NBMUA (Woodcliff). The largest combined sewer area is located in the central and western portions of the Township of North Bergen. The combined sewage in the Central/ Western section of North Bergen Township is conveyed via a pump station and force main to the Jersey City MUA where the flow is then pumped to PVSC's WRRF via the Hudson County force main. The second combined sewer area is generally located on the northeast side of North Bergen, to the east of Bergenline Avenue, and is connected to the North Bergen MUA's Woodcliff STP. The Woodcliff STP service area is separate from the PVSC service area and is covered in a separate System Characterization Report.

The other five municipalities with CSSs are located on the west side of Newark Bay include the Borough of East Newark, the Towns of Harrison and Kearny, and the Cities of Newark and Paterson. These municipalities all own and operate their CSS and permitted by the NJDEP to discharge CSOs. All of these municipalities are tributary to the PVSC Main Interceptor. A portion of the CSSs are tributary to CSO control facilities owned and/or operated by the individual Permittees/Municipalities and a portion of the CSO control facilities are owned and/or operated by PVSC. PVSC owns and operates 45 of the regulator chambers in these communities that control the sewer flow to the PVSC trunk system.

These combined sewer municipalities collectively own and operate a total of 111 CSO outfalls in PVSC's existing Service Area, which ultimately discharge to the waterbodies shown in **Figure C-2**.

C.2.2 Separate Sewer Service Area

In addition to the municipalities with combined systems, separately sewered municipalities convey their flow to the Main Interceptor Sewer through 13 branch intercepting sewers and various direct sewer connections. Forty of the 48 municipalities in the service area have separate sewer systems (does not include storm water), and, therefore, do not own or operate any CSOs. Separate sewer systems make up 61,889 acres of the PVSC service area which is approximately 74 percent of the Total Contributing Area. In all but one municipality with a separate sewer

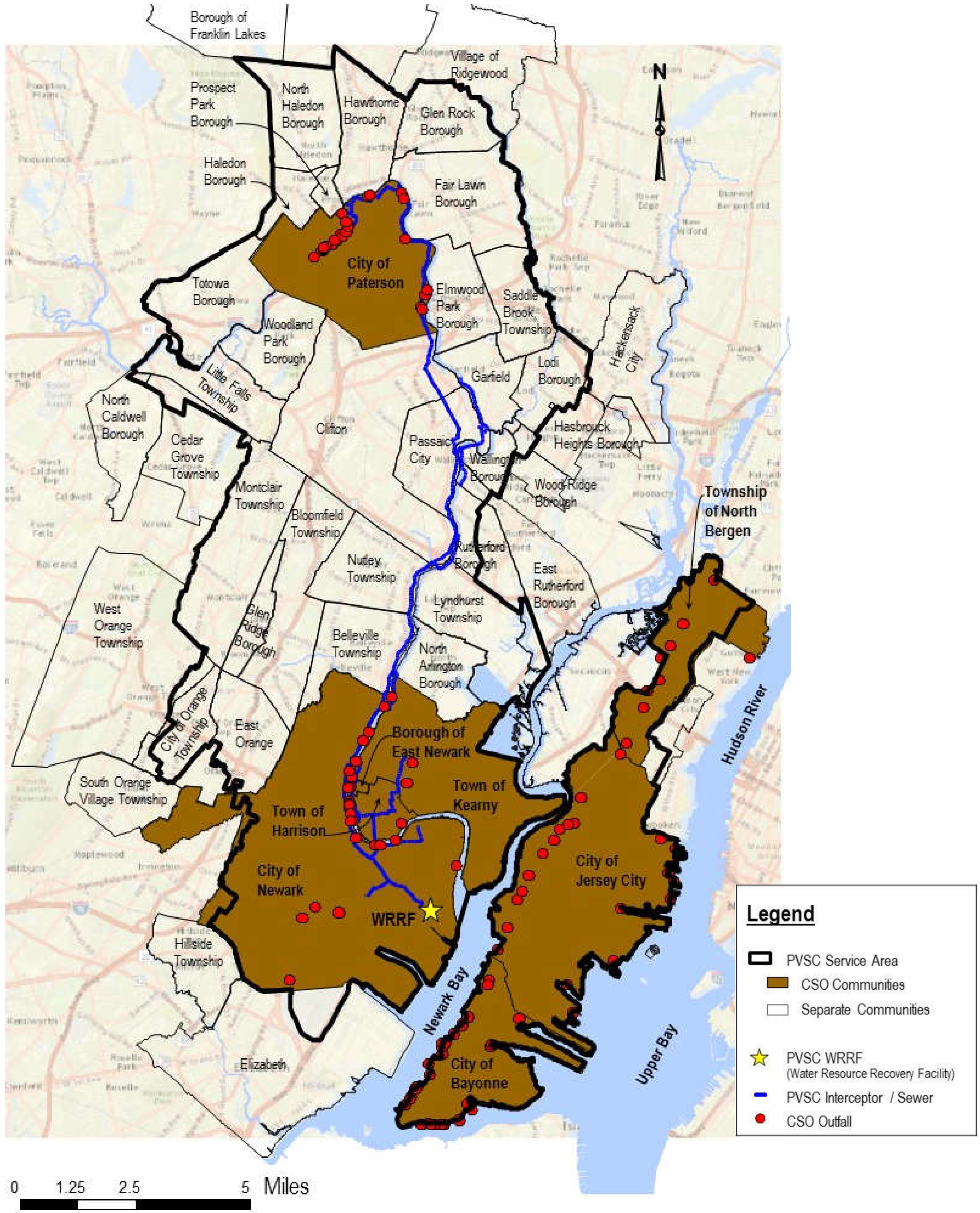


Figure C-2: PVSC Service Area with CSO Outfall Location

system, sewage discharges to the PVSC Main Interceptor and is conveyed to the PVSC WRRF via this interceptor; Union City's sewage flow is conveyed through the Hudson County Force Main and is discharged upstream of the Primary Clarifiers at the PVSC WRRF. See **Table C-1** above for details regarding separate and combined sewer area.

The following Passaic County towns and boroughs listed in **Table C-2** below contribute separate sewage flow to the PVSC WRRF through the Main Interceptor.

Table C-2: Passaic County Separate Sewer Areas

Passaic County	
Franklin Lakes	Woodland Park
North Haledon	Totowa
Hawthorne	Townships of Little Falls
Prospect Park	Cities of Passaic
Haledon	Clifton City

The following towns, boroughs and cities listed in **Table C-3** are located in Bergen County with separate sewage networks are generally located east of the Passaic River and drain into the PVSC Main Interceptor.

Table C-3: Bergen County Separate Sewer Areas

Bergen County	
Ridgewood Village	North Arlington
Glen Rock	Wood Ridge
Fair Lawn	Hasbrouck Heights
Elmwood Park	Saddle Brook
Lodi	Lyndhurst
Wallington	South Hackensack
Rutherford	Hackensack
East Rutherford	Garfield

Table C-4 lists the Essex County towns, boroughs and cities which are located towards the south end of the PVSC Main Interceptor and contribute separate sewage flow to the PVSC WRRF via the Main Interceptor.

Table C-4: Essex County Separate Sewer Areas

Essex County	
Montclair	West Orange
Nutley	South Orange
Belleville	City of East Orange
Bloomfield	Glen Ridge Borough
City of Orange	North Caldwell
Cedar Grove	

The township and city listed in **Table C-5** are in Union County and are located towards the south end of the PVSC Main Interceptor. They contribute separate sewage flow to the PVSC WRRF via the Main Interceptor.

Table C-5: Union County Separate Sewer Areas

Union County	
Hillside Township	Elizabeth City

Union City is the only separate sewerage municipality located in Hudson County and contributes flow directly to the WRRF through the Hudson County Forcemain.

Most CSO Communities have both separate sewer sections and combined sewer areas. The contributing separate sanitary sewer system area for each CSO community is shown in Table C-1. A portion of the City of Bayonne includes a separate sewer system, which serves a small industrial area. Sewage is conveyed separately in the area between Pulaski Street and Constable Hook along the Hudson River and is discharged directly to the Eastern Interceptor Sewer. All wastewater within the City flows to the City of Bayonne Oak Street Pumping Station, which transports wastewater to the PVSC WRRF.

SECTION D - CHARACTERISTICS OF THE COMBINED SEWER SYSTEM

D.1 SOURCES OF COLLECTION SYSTEM DATA

In order to characterize the CSS in the PVSC Service Area, the following previous reports were reviewed and utilized as sources of collection system data:

- North Bergen MUA CSO Characterization Study (March 2005)
- Bayonne Municipal Utilities Authority Facilities Inventory and Assessment Analysis (Sep 2013)
- Bayonne Municipal Utilities Authority CSO Discharge Characterization Report (Nov 2005)
- Bayonne Municipal Utilities Authority CSO LTCP Vol 1 Cost & Performance Analysis Report (Mar 2007)
- PVSC Report on Maximization Flows to WWTP (Oct 2003)
- PVSC Maximization of Wastewater to PVSC (Dec 1996)
- PVSC CSO Modeling Study (Feb 2004)
- PVSC CSO LTCP Vol 1 Cost & Performance Analysis Report March 2007-HMM

D.2 CHARACTERISTICS OF COMBINED SEWER SYSTEM

D.2.1 Description of CSO System

PVSC's sewer system consists of approximately 25 miles of intercepting sewers, eleven (11) branch interceptors with a total length of approximately 13 miles, thirteen (13) lateral sewers, river crossings, regulators, metering equipment, manholes and two (2) pump stations. Flow to the treatment facility is conveyed via two (2) primary interceptors and one primary force main: the Main Interceptor, the South Side Interceptor and the Hudson County Force Main. There are about 2,000 miles of lateral sewers which are owned by the various contributing municipalities which connect to the PVSC Main Interceptor.

D.2.2 Trunk Sewers

The PVSC service district includes over 1,000 miles of combined sewer gravity pipes and trunk sewers. These sewers are owned and maintained by the individual municipalities or authorities. Sewer data was collected from prior reports and GIS to develop and update the system inventory. Most of the pipe characteristics, including upstream and downstream nodes, dimension, shape, number of barrels, and flap gate information, were found or estimated from prior studies, record drawings, design drawings and sewer gravity main GIS shapefiles. If sewer main information was not available, sewer length was estimated in GIS geometry measurement. Manhole information, including invert and rim elevations, were found or estimated from record drawings, design drawings, and existing collection system models.

D.2.3 Flow Diversion Structures and CSO Regulators

There are 59 active regulating chambers tributary to the PVSC interceptors: 27 in Paterson, 17 in Newark, 1 in East Newark, 6 in Harrison, and 8 in Kearny. These regulating chambers are equipped with sandcatcher chambers to collect grit prior to flow entering the flow regulating structure. Under dry weather flow conditions, the flow passes through the sandcatcher and is diverted to the regulator chamber through a regulator gate or an orifice and then to the interceptor. Under wet weather conditions, as the height of the wet weather flow rises in the regulator, it overflows the weir and the excess flow is diverted to the overflow chamber and discharged to the receiving waters as combined sewer overflow. Typically, a tide gate chamber is located between the receiving waters and sandcatcher chamber to prevent the backflow of extraneous river waters into the interceptor. As originally designed, the regulating gate was equipped with a float mechanism to regulate the wastewater flow to the interceptor based on the interceptor levels. However, over a period of time, all of these regulators have been converted to passive control or equipped with sluice gates controlled from the WRRF.

PVSC owns and operates a total of 43 regulators throughout the PVSC sewer service district. PVSC owns and operates all of the regulators in East Newark, Harrison, and Kearny, 12 total, 11 regulators in Newark and 20 regulators located in Paterson. Newark and Paterson own and operate the remaining regulators located in their service area. **Table D-1** below lists permittees, regulator owner / operator and the number of regulators within the permittee's service areas. Harrison recently separated the drainage area for the Dey Street CSO and removed the regulator and outfall from service. Harrison now has 6 CSO outfalls and regulators. NJDEP will be issuing a minor modification NJPDES permit action to remove Dey Street outfall 004A in the near future.

Table D-1: Permittees and Their Regulators

Permittee	Owner / Operator	Number of Regulators
Bayonne*	Bayonne - 18	18
East Newark	PVSC - 1	1
Harrison**	PVSC - 6	6
Kearny	PVSC - 5	5
Newark	PVSC – 11; Newark - 7	18
North Bergen MUA*	North Bergen - 33	33 (Central)
Paterson	PVSC – 20; Paterson - 7	27
Total		**108**

* Do not contribute to the PVSC interceptors

** Harrison's NJPDES permit currently reflects 7 Outfalls. NJDEP will be issuing Harrison a minor modification permit action to remove Dey Street Outfall 004A in the near future and they will remove equipment from regulator.

The City of Bayonne has over the years constructed a combined sewer overflow control facilities and relief sewer to provide hydraulic relief to the CSS. The City's combined sewer system currently includes 17 active regulator structures. The Bayonne regulating chambers do not include a sandcatcher chamber. Under dry weather flow conditions, flow is directed through an opening to the regulator valve and then to the interceptor. Under wet weather conditions, when the height of the wet weather flow rises, it overflows the weir and excess flow is discharged to the receiving waters as a CSO. Typically, a tide gate chamber is located between the receiving waters and diversion chamber to prevent the backflow of extraneous river waters into the interceptor.

The North Bergen MUA has 33 active regulator structures in the central service area. All 33 regulating chambers drain to the Jersey City MUA sewer network. Of the thirty three regulators in the Central Area which is part of the PVSC service area, there are 8 dynamic and 25 static regulators. There are multiple regulators that serve single CSO outfalls. Categories of dynamic regulators include gate, float, gate/float, overflow and bar rack.

D.2.4 Interceptors

The PVSC interceptor sewers consist of two interceptor systems: Main Interceptor Sewer and South Side Intercepting Sewer owned and operated by the City of Newark. For flow measurement purposes, the system has three Venturi meter chambers on the Main Interceptor. All but four municipalities, Jersey City, Bayonne, North Bergen and the South Kearny section of Kearny, are serviced by the PVSC interceptor system as shown in **Figure A-2.**

A total of 11 branch interceptors convey flow to the Main Interceptor. The 11 branch Interceptors are approximately 14.6 miles long. Five of the branch interceptors service combined sewer areas and the remaining six service separately sewered areas. They are identified as follows:

Combined Sewer Area Branch Interceptors

- Lawrence Street Branch Interceptor
- Kearny-East Newark-Harrison Branch Interceptor
- Kearny-Harrison-Newark Branch Interceptor
- Brown Street Branch Intercepting Sewer

Separate Sewer Area Branch Interceptors

- Jabez Street Branch Intercepting Sewer
- Prospect Street Branch Intercepting Sewer
- Warren Street Branch Interceptor
- Garfield-Passaic-Wallington Branch Interceptor
- Rutherford-East Rutherford Branch Intercepting Sewer
- Rutherford-Lyndhurst Branch Intercepting Sewer
- Kearny-North Arlington Branch Interceptor

The City of Bayonne's combined sewer system has three major interceptor sewers: Westerly Interceptor Sewer, Easterly Interceptor Sewer and Southerly Interceptor Sewer.

Each of the interceptors is described in further detail below.

Main Interceptor

The main intercepting sewer is approximately 112,000 feet long and extends from the Passaic Valley Sewerage Commissioners Sewage Treatment Facility in Newark to Prospect Street in Paterson. Between Newark and Paterson, the Main Interceptor connects to 11 branch interceptors, 13 lateral sewers, 2 pump stations (Wallington Pump Station at Passaic and Yantacaw Pump Station at Clifton), and a Main Pump Station and the union Outlet Joint Meeting Interceptor, which is jointly owned and operated by the municipalities of Montclair, Bloomfield and Glen Ridge. The system has 59 active regulators. The Main Interceptor generally follows the west bank of the Passaic River through Newark, Belleville, Nutley, Clifton, Passaic and Paterson. Flows enter the Main Interceptor from branch interceptors, regulators and local sewers, and are conveyed to the PVSC WRRF. There are a total of 257 manholes on the Main Interceptor, including the manholes of three Venturi meter chambers and two river siphons.

The Main Interceptor is constructed of poured in place concrete and its shape and size vary depending on location and construction methods (tunnel or open cut) employed in a given reach. At its downstream end in Newark, it is semi-elliptical and 12.5 ft. high, reducing to 10.5 ft. high semi-elliptical at the north Newark boundary. The Main Interceptor's slope varies from 0.0002 to 0.0003. The crossing under Second River at the Newark/Belleville boundary consists of two 7-ft. diameter siphons. At the siphon outlet, there is a Venturi meter chamber with three 36-inch diameter Venturi tubes and a bypass conduit. The siphon inlet is also a sand catcher chamber. At Academy Street in Belleville, the size of the Main Interceptor reduces to 10.0 ft. high semielliptical. Through Nutley, the Main Interceptor has a uniform 10-ft high semi-elliptical cross-section. The slope is 0.0003. At the northern boundary of Nutley, the Third River crossing consists of two 6.5-ft. diameter siphons. The siphon inlet is also a sand catcher chamber. Through the southern portion of Clifton, the sewer has a 9.0-ft. high semi-elliptical cross section, and a constant slope of 0.00035. An emergency by-pass is located in Clifton just north of Clifton-Nutley boundary at Yantacaw Street. Immediately upstream of the southern Passaic boundary, the flow passes through the Passaic Venturi Meter chamber which consists of two 36-inch diameter Venturi tubes and a meter bypass conduit. In Passaic, the interceptor cross section varies from 9 ft. to 7.5 ft. semi-elliptical. Slopes vary from 0.00035 to 0.00042. Through the northern section of Clifton, the interceptor cross section varies from 7.5 ft. semielliptical, to 6.75 ft. circular and subsequently to 6.75 ft. semi-elliptical. Slopes vary from 0.00049 to 0.00042. At the Clifton-Paterson boundary, flow passes through the Paterson meter chamber at Market Street, which includes a single 36-inch diameter Venturi tube and a meter bypass pipe. Through its reach in Paterson to the end, on the western and southern banks of the Passaic River, the cross section of the Main Interceptor changes from 6.75 ft. semi-elliptical to 3.75 ft. circular. Slopes through the Paterson reach vary from 0.00042 to 0.00073.

South Side Interceptor

The South Side Interceptor carries wastewater from the south portions of the City of Newark to the PVSC WRRF in Newark. Constructed in the mid 1960's of reinforced concrete pipe, it is approximately 21,000 feet long and extends from the Main Interceptor just upstream of the head end of the Passaic Valley Sewerage Commissioners Sewage Treatment Plant on Wilson Avenue to Waverly Street Regulator in Newark. It is owned and operated by the City of Newark.

The interceptor transports flows from three regulators owned by the City of Newark, Peddie, Queen and Waverly Street Regulators. At the Main interceptor it is an 84-inch diameter pipe, changes to 66 inch diameter pipe upstream of Peddie Street regulator, and terminates as a 54-inch diameter circular pipe between the Queen and Waverly Street regulators.

Lawrence Street Branch Interceptor

The Lawrence Street Branch Interceptor is approximately 2,839 feet long and extends from the Main Interceptor at the intersection of River and Lawrence Streets to the Northwest Street Regulator in Paterson. The interceptor generally follows Presidential Boulevard, Hudson Street, under the Passaic River onto Lawrence Street, to the intersection of River Street. Flows enter the interceptor through local sewers, the Northwest Street Regulator, Arch Street Regulator, Jefferson Street Regulator, Stout Street Regulator, North Straight Street Lateral Sewer, Hudson Street Regulator and the Lawrence Street Regulator and are conveyed via a direct connection to the Main Interceptor just upstream of Manhole MI-239 as per the FIAA.

There are a total of 21 manholes on the Lawrence Street Branch Interceptor. The interceptor is constructed of poured in place concrete and is 30 inches in diameter at its upstream end. The size increases to 36-inch diameter at the intersection of Presidential Boulevard and Freeman Street. Its slope varies from 0.0009 to 0.00144.

Kearny-East Newark-Harrison Branch Interceptor

The Kearny-East Newark-Harrison Branch Interceptor is approximately 8,948 feet long and extends from the Kearny-Harrison-Newark Branch Interceptor upstream of KHN-5 on Frank E. Rogers Blvd. in Harrison, to the Nairn Street Regulator in Kearny. The Kearny-East Newark-Harrison Branch Interceptor generally follows Essex Street, First Street, Bergen Street, Dey Street, Passaic Avenue and Nairn Avenue.

Flows enter the interceptor through the local sewers, the First Street Lateral Sewer, Bergen Street Lateral Sewer, Dey Street Regulator, Harrison Avenue Regulator, Cleveland Avenue Regulator, New Street Regulator, Central Avenue Regulator, Johnston Avenue Regulator, Marshall Street Regulator and the Nairn Avenue Regulator and are conveyed to the Kearny-Harrison-Newark Branch Interceptor upstream of KHN-5. Flows are metered at two separate locations along the route, the East Newark Meter Chamber and the Johnston Avenue Meter Chamber.

There are a total of 41 Manholes on the Kearny-East Newark-Harrison Branch Interceptor. The interceptor is an 18-inch diameter concrete encased vitrified clay pipe at its upstream end. The size increased to 24-inch diameter poured in place concrete pipe downstream of the Marshall Street Regulator. The pipe size increased again to 33 inches in diameter near the Johnston Avenue Regulator.

The final pipe size change tasks place upstream of the Central Avenue Regulator to 36 inches in diameter. Over the length of the interceptor, the slope varies from 0.00354 to 0.00075.

Kearny-Harrison-Newark Branch Interceptor

The Kearny-Harrison-Newark (KHN) Branch Interceptor is approximately 15,355 feet long and extends from the Main Interceptor at the intersection of Ferry Street and Van Buren Street to north of King Street on Schuyler Avenue in Kearny. The Kearny-Harrison-Newark Branch Interceptor generally follows Van Buren Street and Raymond Boulevard in Newark, South Fourth Street, Essex Street, 7th Street, Bergen Street, Manor Avenue, Ann Street, Worthington Avenue, Kingsland Avenue in Harrison and Hamilton Avenue and Schuyler Avenue in Kearny.

Flows enter the Kearny-Harrison-Newark Branch Interceptor from the Brown Street Branch Interceptor, Kearny-East Newark-Harrison Branch Interceptor, Bergen Street Lateral, Duke and Tappan Street Lateral, local Sewers and service connections and are conveyed to the Main Interceptor upstream of Manhole MI-15. Flows entering the Kearny-Harrison-Newark Branch Interceptor are regulated by five regulators: the Bergen Street Regulator, Worthington Avenue Regulator, Duke Street Regulator, Tappan Street Regulator and Ivy Street Regulator.
There are a total of 43 manholes on the Kearny-Harrison-Newark Branch Interceptor including the manholes of one combined sewer overflow chamber, one flume type meter chamber, and one venturi type meter chamber. Also included are the inlet and outlet siphon chamber manholes.

The Kearny-Harrison-Newark Branch Interceptor is constructed of poured in place concrete pipe. The downstream end of the pipe is 64 inches in diameter and has a slope of 0.0038. The pipe size reduces to 54-inch diameter at a slope of 0.00049 in the vicinity of Passaic Avenue. The interceptor crosses the Passaic River under the Jackson Street Bridge as a 48 inch circular siphon at a slope of 0.00066. Through the southern portion of Harrison, the pipe size is 56 inches in diameter at a slope of 0.00039 to upstream of the intersection with Kearny-East Newark-Harrison Branch Interceptor, where, the diameter changes to 48 inches at a varying slope of approximately 0.00054. At manhole KHN-19, the pipe size changes to 42-inch diameter at a slope of 0.00065 and changes again at Manhole KHN-26 to 36-inch diameter at a slope of 0.00118.

Brown Street Branch Intercepting Sewer

The Brown Street Branch Intercepting Sewer is approximately 6,867 feet long and extends from the Kearny-Harrison-Newark Branch Intercepting Sewer at the intersection of Van Buren Street and Raymond Boulevard to the inactive Brown Street Regulator in Newark. The Interceptor generally follows Raymond Boulevard, Passaic Avenue, Cornelia Street, Lister Street and Brown Street. Flows enter the interceptor through the local sewers, the Freeman Street Regulator and the Polk Street Regulator and are conveyed via a direct connection to the Kearny-Harrison-Newark Branch Interceptor between Manholes KHN-1 and KHN-2.

There are a total of 29 manholes on the Brown Street Branch Intercepting Sewer. The interceptor is constructed of poured in place concrete and is a 24-inch diameter circular pipe at its upstream end. Its size increases to 48 inch at Raymond Boulevard and Freeman Street. Its slope is 0.0014.

Jabez Street Branch Intercepting Sewer

The Jabez Street Branch Intercepting Sewer is approximately 3,340 feet long and extends from the Main Interceptor at the intersection of Jabez Street and Wilson Avenue to the South Bay Avenue Regulator in Newark. The South Bay Regulator is currently inactive. The interceptor generally follows Jabez Street, Backus Street and Wheeler Point Road to South Bay Avenue. Flows enter the Interceptor through the South Bay Street Regulator and local sewers and are conveyed through a direct connection to the Main Interceptor between MI-13 and MI-14.

There are a total of 4 manholes on the Jabez Street Branch Intercepting Sewer including one manhole of the South Bay Avenue Regulator.

The Interceptor is a 57-inch circular poured in place concrete pipe over its entire length. Its slope varies from 0.001 to 0.002733.

Prospect Street Branch Intercepting Sewer

The Prospect Street Branch Intercepting Sewer is approximately 1,377 feet long and extends from the Main Interceptor at the intersection of River and Prospect Streets to the S.U.M. Park Regulator on Ryle Avenue in Paterson. The Interceptor generally follows the Passaic River in an easterly direction and crosses underneath the Passaic River by gravity. Flows enter the interceptor from the S.U.M. Park Regulator and local sewers and are conveyed to the Main Interceptor via a direct connection between MI-247 and MI-248.

There are a total of nine manholes on the Prospect Street Branch Intercepting sewer including manholes of the S.U.M. Park Regulator. The interceptor is a 16-inch diameter cast iron pipe at its upstream end, changes to a 24-inch x 16-inch elliptical concrete pipe before reaching its terminal size of 15 inches. Its slope varies from 0.0022 to 0.0080.

Warren Street Branch Interceptor

The Warren Street Branch Intercepting Sewer is approximately 1,967 ft. long and extends from the Main Interceptor at the intersection of Warren and River Streets to the Short Street Regulator in Paterson. The interceptor generally follows the west bank of the Passaic River form Short Street to East Holsman Street. At East Holsman Street, the interceptor crosses under the Passaic River and follows Warren Street to the Main Interceptor. Flows enter the interceptor from the Short Street Regulator, Warren Street Regulator, Bergen Street Regulator and local sewers and are conveyed to the Main Interceptor at Manhole MI-234.

There are a total of 15 manholes on the Warren Street Branch Interceptor, including the regulator manholes. The interceptor is a 24-inch diameter poured in place concrete pipe from its upstream end to East Holsman Street. The siphon at East Holsman Street is an 18-inch diameter cast iron pipe. At the siphon outlet, the interceptor increases to its terminal size of 30 inches in diameter.

Garfield-Passaic-Wallington Branch Interceptor

The Garfield-Passaic-Wallington (GPW) Branch Interceptor is approximately 12,387 feet long and extends from the Wallington Pumping Station in Passaic to the intersection of River Drive and Outwater Lane in Garfield. The interceptor generally follows Lester Avenue, Lodi Street, Eighth Street, Passaic Street, Tenth Street and River Drive. Flows enter the interceptor through local sewers, the Passaic-Tail Race Regulator (inactive), Dundee Lateral Sewer, Passaic Street Lateral Sewer, Wall Street Lateral Sewer, and are conveyed via a direct connection to the Main Interceptor, 87 feet upstream of MI-122. Flows are metered at two locations along the route, Garfield Meter Chamber and the Lodi Street Meter Chamber.

There are a total of 54 manholes on the Garfield-Passaic-Wallington Branch Interceptor. The Interceptor is typically constructed of poured in place concrete. A small section is concrete encased vitrified clay pipe. The concrete encased vitrified clay pipe located at the upstream end is 18 inches in diameter with a slope of .00170.

The interceptor size and slope change to 27-inch diameter with a slope of 0.00110 at Manhole GPW-48. At Manhole GPW-44, the pipe size changes to 30-inch diameter at a slope of 0.0014. The pipe size changes to 33-inch diameter with a slope of 0.0010 at Manhole GPW-33. One manhole upstream of the Garfield Meter Chamber, GPW-22, the pipe size changes to 36-inch diameter. At the outlet of the Garfield siphon, the pipe becomes 42 inches in diameter and continues at that size to Manhole GPW-10, where it changes to 48 inches. The slope is approximately 0.00085. The outlet pipe at the Lodi Meter Chamber is 54 inches in diameter at a slope of 0.00085 and terminates at the Wallington siphon inlet chamber. The siphon has a 30-inch diameter and a 48-inch diameter pipe running in parallel under the Passaic River.

The last stretch of pipe runs from the outlet siphon to the Wallington Pumping Station and is 54 inches in diameter.

Rutherford-East Rutherford Branch Intercepting Sewer

The Rutherford-East Rutherford (RER) Branch Intercepting Sewer is approximately 4,943 feet long and extends from the Wallington Pumping Station Regulator in Wallington to Memorial Park in East Rutherford. The interceptor generally follows Madison Street, Carlton Avenue, Paterson Avenue and VanWinkle Avenue to the Wallington Pump Station Regulator. Appurtenances on the Interceptor include the East Rutherford and the Rutherford Meter Chambers. Flow enters the Interceptor through local sewers, house connections, and the VanWinkle Meter Chamber.

There are a total of 25 manholes on the Rutherford-East Rutherford Branch Intercepting Sewer. The sewer is constructed of 24-inch diameter poured in place concrete at its upstream end. Its size increases to 27-inch diameter at RER-8 and to 36-inch by 27-inch semi-elliptical and then to 36-inch circular near the intersection of Main Avenue and VanWinkle Avenue in Wallington. Small segment of the 36-inch pipe and the 36-inch by 27-inch semi-elliptical pipe along VanWinkle Avenue are constructed of brick.

Rutherford-Lyndhurst Branch Intercepting Sewer

The Rutherford-Lyndhurst Branch Intercepting Sewer is approximately 5,893 ft long and extends from the Yantacaw Pumping Station in Clifton to the Woodward Avenue Regulator in Rutherford. The sewer generally follows Riverside Avenue and conveys flows from the

Rutherford, Pierrepont and Woodward Avenue Regulators, local sewers and service connections to the Yantacaw Pumping Station.

There are a total of 25 manholes on the Rutherford-Lyndhurst Branch Intercepting Sewer including the manholes of one meter chamber and the three aforementioned regulators. The interceptor is an 18-inch diameter concrete cradled vitrified clay pipe at its upstream end and increases to a 24-inch diameter poured in place concrete pipe at its downstream end. Its slope varies from 0.0012 to 0.0013. Appurtenances along the interceptor include a meter chamber, the Rutherford Avenue Regulator, the Pierrepont Avenue Regulator and the Woodward Avenue Regulator.

Kearny-North Arlington Branch Interceptor

The Kearny-North Arlington (KNA) Branch Interceptor is approximately 5,330 feet long and extends from the Main Interceptor on Academy Street in Belleville to North Midland Avenue in Kearny. The Kearny-North Arlington Branch Interceptor generally follows the east bank of the Passaic River through North Arlington and Kearny. Flows enter the Kearny-North Arlington branch Interceptor through the Stewart Avenue and Washington Avenue Regulators, local sewers and a number of house connections and are conveyed to the Main Interceptor through the North Arlington Siphon.

There are a total of 31 manholes on the Kearny-North Arlington Branch Interceptor, including the manholes of the two meter chambers and the North Arlington Branch Regulator.

The Kearny-North Arlington Branch Interceptor is constructed of poured in place concrete pipe and concrete encased vitrified clay pipe. The siphon is 20-inch diameter cast iron pipe. Between the siphon outlet chamber and KNA-4, the sewer is a 24-inch diameter concrete pipe with a slope of 0.0011. At KNA-4, the pipe changes to an 18-inch diameter concrete encased vitrified clay pipe with a slope of 0.0014. At KNA-12, the size of the pipe changes to 12-inch diameter concrete encased vitrified clay pipe to the upstream end of the branch interceptor. Throughout the 12-inch diameter section, the slope of the pipe varied from 0.000068 to 0.00089.

Westerly Interceptor Sewer

Bayonne's Westerly Interceptor Sewer generally runs along Newark Bay and ranges from 12 inches to 48 inches in diameter. The interceptor discharges to the West 22nd Street Sewage Pumping Station which sends flow to the Easterly Interceptor.

Easterly Interceptor Sewer

Bayonne's Easterly Interceptor Sewer generally runs along Route 440 and Avenue F, and ranges from 42 inches to 72 inches in diameter. The interceptor discharges to the Oak Street Pumping Station.

Southerly Interceptor Sewer

Bayonne's Southerly Interceptor Sewer is generally routed along the Kill Van Kull and ranges from 24 inches to 54 inches in diameter. The interceptor discharges to the Oak Street Pumping Station.

D.2.5 Pump Stations

PVSC's Main Interceptor has two pump stations – the Wallington Pump Station and the Yantacaw Pump Station. Both pump stations were built in the year 1924 and have undergone several interim modifications since.

The Wallington Pump Station is located in the Borough of Wallington within Bergen County and serves the municipalities of Wallington, Garfield, East Rutherford, and portions of Passaic, Rutherford, and Saddle Brook. The pump station is equipped with two 75 HP and one 125 HP dry pit submersible pumps, with a wet well and dry well arrangement. Wastewater enters the pump station through a 54-inch diameter pipe (Lodi Force Main) and passes through screening equipment. The pump station discharges flow through a 36-inch diameter force main. The station has an emergency generator, electrical power distribution equipment, HVAC equipment, and instrumentation.

The Yantacaw Pump Station is located in the City of Clifton in Passaic County and serves portions of Lyndhurst and Rutherford. The Pump Station is equipped with three 50 HP dry pit submersible pumps, with a wet well and dry well arrangement. Wastewater enters the Pump Station through a 24-inch diameter pipe and passes through screening equipment. The pump station discharges flow through an 18-inch diameter force main. The station has an emergency generator, electrical power distribution equipment, HVAC equipment, and instrumentation.

The City of Bayonne operates four pumping stations; West 22nd St, Oak St, West 1st St and 5th Street Pumping stations, two on the combined sewer system and two on the relief sewer system.

- The West 22nd Street Sewage Pumping Station is located at the end of West 22nd Street, near Newark Bay. This Pumping Station pumps flows between the Westerly Interceptor and the Easterly Interceptor. The station is equipped with two pumps, and has a pumping capacity of 25 MGD.
- The Oak Street Pumping Station is located at Oak Street and 5th Street. This Pumping Station pumps flows from the Easterly and Southerly Interceptor Sewers to PVSC. The station is equipped with four (4) pumps, and has a pumping capacity of 57.6 MGD. 17.6 MGD of that flow can be pumped to PVSC, and the remaining 40 MGD is pumped to an outfall.
- The West 1st Street Pumping Station is located on West 1st Street near Humphreys Avenue. This Pumping Station relieves the Southerly Interceptor when hydraulic head increases beyond the crown of the pipe. This station is equipped with two pumps and has a pumping capacity of 6 MGD.\
- The 5th Street Pumping Station is located at 5th Street and Ingraham Avenue. This Pumping Station accepts stormwater and combined sewer overflows, and discharges to an inlet tributary to the Kill Van Kull. This station is equipped with eight pumps and has a pumping capacity of 300 MGD.

North Bergen MUA owns and operates three pumping stations; Central PS, 8th Street PS, and 61st Street Pumping Stations. Approximately 7 MG dry weather flow of combined sewage per day is pumped from North Bergen to Jersey City MUA's CSS for ultimate conveyance to the PVSC WRRF via the Hudson County force main.

Kearny has one pump station; the South Kearny Pump Station that has a maximum capacity of 17.5 MGD. This pump station discharges directly the PVSC WRRF.

D.2.6 Force Mains

The Hudson County force main ranges in size from 54 inches to 72 inches and is primarily comprised of prestressed concrete cylinder pipe. The force main was installed in the late 1980s and was relocated in two locations in Jersey City in 1997. PVSC maintains approximately 10,000 feet of the force main from the Jersey City emergency overflow structure, which is located under Newark Bay, to the connection into PVSC's influent pumping station just prior to PVSC's primary clarifiers.

Bayonne's West 22nd Street Sewage Pumping Station pumps to a 30-inch force main which discharges to the Westerly Interceptor. Bayonne's Oak Street Pumping Station pumps to a 36-inch force main which discharges into the Hudson County force main in Jersey City.

D.2.7 CSO Control Facilities

Of the regulators to the PVSC interceptors, ten in Newark have been retrofitted and equipped with motorized sluice gates, which are remotely controlled from the plant via a telemetered control signal. PVSC operates the ten Newark sluice gates with radio transmission through Phoenix contact and Elpro™ transmitters back to PVSC's SCADA system. The gates can be utilized during rain events to prevent overloading the WRRF. The appropriate gates may be controlled to bypass the combined sewer from the regulator to the Passaic River. Newark has 16 CSO Control Facilities, 12 Netting Facilities and 4 Screening Facilities. Three of the netting facilities are currently under construction with a completion date of September 2018.

The South Side Interceptor has a gate that can be manually closed in the event of an emergency situation, causing a diversion of the entire flow to the Newark Airport Peripheral Ditch.

The City of Bayonne owns and operates 17 CSO control facilities and 17 discharge points originating at regulator chambers to the interceptor sewers. In addition to the CSO points originating at regulators to the interceptor, the City has constructed new CSO control facilities to provide hydraulic relief to the CSS. While catch basins in the area of the relief sewer were directly connected, catch basins in upstream areas remain connected to the combined sewer system. Control facilities, such as overflow pipes or weirs, divert excess wastewater flow from the combined sewer collection system to the receiving waters. Overall the relief sewer system contains 37 control facilities tributary to 13 CSO discharge pipes. As construction of solids/floatables control facilities were undertaken, several of the outfalls were combined to reduce the number of individual facilities.

The North Bergen MUA has 8 netting facilities and 1 bar screen in the Central Service Area and one netting facility in the Woodcliff Service Area. While several of the CSO outfalls receive flows from only one control facility, the other systems contain multiple control points.

Harrison Town owns and operates 6 CSO Floatable Control Facilities.

D.2.8 CSO Outfalls

Table D-2 lists all of the CSO outfalls, associated permittees, permit numbers and the waterbodies into which they discharge in the PVSC Service Area. PVSC CSO Sewer District receiving waters include the Passaic River, Newark Bay, Upper New York Bay, Hackensack River, Hudson River, Kill Van Kull, as well as their tributaries. There are a total of 90 outfalls within the PVSC Service District located in the Towns of Bayonne, East Newark, North Bergen and the Cities of Harrison, Newark and Paterson.

Overall the City of Bayonne has 28 CSO outfall pipes. Sixteen of the CSO points discharge to Newark Bay. Nine flow to the Kill Van Kull and three drain to the Hudson River. All facilities are currently owned and operated by the City of Bayonne.

East Newark Borough has one CSO outfall. This single outfall has solids/floatables removal equipment installed upstream of the point of discharge. The outfall discharges in to the Passaic River.

Harrison Town has six CSO outfalls that are all equipped with solids/floatables removal equipment installed upstream of the point of discharge. All six of the CSO outfalls discharge in to the Passaic River. Harrison previously had seven CSO's but separated the drainage area associated with Outfall 004A and closed the outfall. The NJDEP will be issuing Harrison a minor modification NJPDES permit action to remove Dey Street outfall 004A in the near future.

Newark City has 18 CSO outfalls including the Queen Street outfall that has been reactivated. Ten of the CSO outfalls are equipped with solids/ floatables removal equipment installed upstream of the point of discharge. The CSO outfalls discharge into the Passaic River and the Elizabeth Channel.

The North Bergen MUA's Central CSS is part of the PVSC's WRRF collection system has nine CSO outfalls that are permitted, owned and operated by the North Bergen MUA. One outfall discharges to Bellmans Creek, six discharge to Cromakill Creek and two discharge to Penhorn Creek which drain to the Hackensack River. During dry weather conditions, all of the wastewater flows from the western and central portions of the North Bergen is ultimately conveyed to the PVSC WRRF in Newark, NJ via the Jersey City MUA pump station and the Hudson County force main. During wet weather periods when the capacity of the collection system is exceeded, combined sewage will be discharged as a CSO from one or more of North Bergen MUA's nine outfalls. North Bergen MUA's Woodcliff STP service area has one CSO outfall that is owned and operated by the North Bergen MUA and discharges to the Hudson River.

The City of Paterson has 23 CSO outfalls. Nineteen of the twenty three have solids/floatables removal equipment installed upstream of the point of discharge. All twenty three CSO outfalls discharge in to the Passaic River.

The Town of Kearny has five CSO outfalls. All five CSO outfalls have solids/floatables removal equipment installed upstream of the point of discharge. The CSO outfalls discharge in to the Passaic River and Frank's Creek.

Table D-2: CSO Outfalls and Their Receiving Waters

SPDES	Permittee	CSO Number	Receiving Water Body
NJ0109240	Bayonne	001A	Kill Van Kull
NJ0109240	Bayonne	002A	Kill Van Kull
NJ0109240	Bayonne	003A	Kill Van Kull
NJ0109240	Bayonne	004A	Kill Van Kull
NJ0109240	Bayonne	006A	Upper NY Bay
NJ0109240	Bayonne	007A	Upper NY Bay
NJ0109240	Bayonne	008A	Kill Van Kull
NJ0109240	Bayonne	009A	Kill Van Kull
NJ0109240	Bayonne	010A	Kill Van Kull
NJ0109240	Bayonne	011A	Newark Bay
NJ0109240	Bayonne	012A	Newark Bay
NJ0109240	Bayonne	013A	Newark Bay
NJ0109240	Bayonne	014A	Newark Bay
NJ0109240	Bayonne	015A	Newark Bay
NJ0109240	Bayonne	016A	Newark Bay
NJ0109240	Bayonne	017A	Newark Bay
NJ0109240	Bayonne	018A	Newark Bay
NJ0109240	Bayonne	019A	Newark Bay
NJ0109240	Bayonne	020A	Newark Bay
NJ0109240	Bayonne	021A	Upper NY Bay
NJ0109240	Bayonne	022A	Newark Bay
NJ0109240	Bayonne	024A	Kill Van Kull
NJ0109240	Bayonne	026A	Newark Bay
NJ0109240	Bayonne	028A	Newark Bay
NJ0109240	Bayonne	029A	Newark Bay
NJ0109240	Bayonne	030A	Newark Bay
NJ0109240	Bayonne	034A	Newark Bay
NJ0109240	Bayonne	035A	Newark Bay
NJ0109240	Bayonne	036A	Newark Bay

SPDES	Permittee	CSO Number	Receiving Water Body
NJ0109240	Bayonne	037A	Kill Van Kull
NJ0117846	East Newark	001A	Passaic River
NJ0108715	Guttenberg	001A	Hudson River
NJ0108871	Harrison Town	001A	Passaic River
NJ0108871	Harrison Town	002A	Passaic River
NJ0108871	Harrison Town	003A	Passaic River
NJ0108871	Harrison Town	005A	Passaic River
NJ0108871	Harrison Town	006A	Passaic River
NJ0108871	Harrison Town	007A	Passaic River
NJ0111244	Kearny Town	001A	Passaic River
NJ0111244	Kearny Town	004A	Passaic River
NJ0111244	Kearny Town	006A	Passaic River
NJ0111244	Kearny Town	007A	Frank's Creek
NJ0111244	Kearny Town	010A	Frank's Creek
NJ0108758	Newark City	002A	Passaic River
NJ0108758	Newark City	003A	Passaic River
NJ0108758	Newark City	004A	Passaic River
NJ0108758	Newark City	005A	Passaic River
NJ0108758	Newark City	008A	Passaic River
NJ0108758	Newark City	009A	Passaic River
NJ0108758	Newark City	010A	Passaic River
NJ0108758	Newark City	014A	Passaic River
NJ0108758	Newark City	015A	Passaic River
NJ0108758	Newark City	016A	Passaic River
NJ0108758	Newark City	017A	Passaic River
NJ0108758	Newark City	018A	Passaic River
NJ0108758	Newark City	022A	Passaic River
NJ0108758	Newark City	023A	Peripheral Ditch / Elizabeth Channel
NJ0108758	Newark City	025A	Peripheral Ditch / Elizabeth Channel
NJ0108758	Newark City	026A*	Queen Ditch
NJ0108758	Newark City	027A/029A	Peripheral Ditch / Elizabeth Channel
NJ0108758	Newark City	030A	Peripheral Ditch / Elizabeth Channel
NJ0108898	North Bergen MUA	003A	Bellmans Creek
NJ0108898	North Bergen MUA	005A	Cromakill Creek

SPDES	Permittee	CSO Number	Receiving Water Body
NJ0108898	North Bergen MUA	006A	Cromakill Creek
NJ0108898	North Bergen MUA	007A	Cromakill Creek
NJ0108898	North Bergen MUA	008A	Cromakill Creek
NJ0108898	North Bergen MUA	009A	Cromakill Creek
NJ0108898	North Bergen MUA	010A	Cromakill Creek
NJ0108898	North Bergen MUA	011A	Cromakill Creek
NJ0108898	North Bergen MUA	014A	Cromakill Creek
NJ0029084	North Bergen MUA	004A	Hudson River
NJ0108880	Paterson City	001A	Passaic River
NJ0108880	Paterson City	003A	Passaic River
NJ0108880	Paterson City	005A	Passaic River
NJ0108880	Paterson City	006A	Passaic River
NJ0108880	Paterson City	007A	Passaic River
NJ0108880	Paterson City	010A	Passaic River
NJ0108880	Paterson City	013A	Passaic River
NJ0108880	Paterson City	014A	Passaic River
NJ0108880	Paterson City	015A	Passaic River
NJ0108880	Paterson City	016A	Passaic River
NJ0108880	Paterson City	017A	Passaic River
NJ0108880	Paterson City	021A	Passaic River
NJ0108880	Paterson City	022A	Passaic River
NJ0108880	Paterson City	023A	Passaic River
NJ0108880	Paterson City	024A	Passaic River
NJ0108880	Paterson City	025A	Passaic River
NJ0108880	Paterson City	026A	Passaic River
NJ0108880	Paterson City	027A	Passaic River
NJ0108880	Paterson City	029A	Passaic River
NJ0108880	Paterson City	030A	Passaic River
NJ0108880	Paterson City	031A	Passaic River
NJ0108880	Paterson City	032A	Passaic River
NJ0108880	Paterson City	033A	Passaic River

*To be reactivated

D.2.9 Green Infrastructure

Various green infrastructure and source control projects have been implemented across the PVSC service area. Several communities have implemented rain barrel give-away programs or workshops for residents. Rutgers University's Cooperative Extension Water Resource Program has performed Green Infrastructure Feasibility Studies for almost all of the 48 municipalities within the service area. Several of the projects identified by the Rutgers' Feasibility Studies have already been implemented, including rain gardens, cisterns, and planter boxes. In addition, municipal action teams have been formed in most of the combined sewer communities. These municipal action teams are advancing green infrastructure and sustainable practices within their communities. The Green Infrastructure projects will help to intercept runoff from impervious areas such as roads, driveways, parking lots, and roofs and redirect this flow to green infrastructure, thereby reducing the total wet weather flow to the combined sewer system. See **Table I-7** for the percent impervious area in the model area.

SECTION E - COLLECTION OF PRECIPITATION AND SEWER FLOW MONITORING DATA

E.1 INTRODUCTION

This section presents information on the collection of precipitation and sewer flow data to meet the requirements of Paragraphs II.A.C.1.a and b of the USEPA's CSO Control Policy.

Rainfall and flow monitoring data were collected from April 2016 to August 2016. After the collected data was reviewed and analyzed, the data was deemed adequate to facilitate the development, calibration and validation of the Hydrologic and Hydraulic (H&H) Model. This section contains a summary of the rainfall and flow monitoring data and discusses the network of rainfall and flow monitoring instrumentation, and describes how the data collected for the rainfall and flow monitoring program was analyzed for use in the H&H Model calibration and validation.

E.2 SEWER FLOW MONITORING PROGRAM

PVSC owns and operates a flow monitoring network across the PVSC Service Area. The monitoring network includes various types of flow meters located throughout PVSC's Service Area, at the WRRF, in each of the Pump Stations, and at the tie-in points where other municipal collection systems tie-into the collection system. There are over 70 permanent flow meters out of which 58 were used for dry weather flow analysis and calibration, which includes 38 existing flow meters in the separate sewer areas (outside the CSO area), 14 existing flow meters at pump stations and one existing flow meter at WRRF were used for the calibration and validation of the H&H Model. In addition, temporary flow meters were installed at 21 new locations to characterize surface runoff from the combined area and CSO discharges. The locations of flow meters installed specifically for the flow monitoring program and the H&H Model calibration and validation can be categorized into the following four categories:

1. Located on the influent pipe to CSO regulators to measure the influent flow to CSO regulators and for combined area runoff calibration. Five meters were installed for this category.
2. Located on the effluent pipe and overflow pipe of CSO regulators to measure the CSO overflows and calibrate CSO regulator parameters. Two meters were installed for this category.
3. Located on the overflow pipe of CSO regulators to measure the CSO overflows and calibrate CSO regulator parameters. Thirteen meters were installed for this category.
4. Located in the main interceptors to measure level and flows in the major interceptors. One meter was installed for this category.

Table E-1 lists the flow meter locations and location categories of the meters. **Figure E-1** shows the locations of the flow meters that were used for H&H Model calibration and validation.

Table E-1: Temporary Flow Meter Locations

Meter ID	Municipality	Location	Category
Bayonne 008A OF	Bayonne	East 5th and Ingham Ave	Outfall
Bayonne 010A OF	Bayonne	W 1st and Avenue C	Outfall
Guttenberg 001A	Guttenberg	70th and JFK Blvd	Outfall
Harrison 006 Influent	Harrison	Bergen and Dey	Regulator Influent
Kearny 007A	Kearny	King and Ivy Street	Outfall
Newark 004/005A	Newark	Herbert Place under elevated Hwy	Outfall
Newark 009/010 OF North	Newark	Clay Street - inside facility	Outfall
Newark 009/010 OF South	Newark	Clay Street - inside facility	Outfall
Newark 015A	Newark	City Dock	Outfall
Newark 014A	Newark	Saybrook in pull off	Outfall
Newark 025A East	Newark	Peddie - access through parking, near railroad	Regulator Influent
Newark 025A West	Newark	Peddie - access through parking, near railroad	Regulator Influent
Newark 025A Regulated	Newark	Peddie - access through parking, near railroad	Regulator Effluent
North Bergen 004A	North Bergen	73rd and Hudson County 693	Outfall
North Bergen 004B	North Bergen	Near 74th and Hudson County in grassy lot	Outfall
North Bergen 007A	North Bergen	53rd and Tonnelle Ave in Concrete Plant driveway	Outfall
North Bergen 011A	North Bergen	1101 Tonnelle Ave	Outfall
Paterson 006A East	Paterson	Montgomery and River St	Regulator Influent
Paterson 006A West	Paterson	Montgomery and River St	Regulator Influent
Paterson 006A Regulated	Paterson	Montgomery and River St	Regulator Effluent
Paterson_INT	Paterson	McLean Boulevard at Cemetery entrance	Interceptor

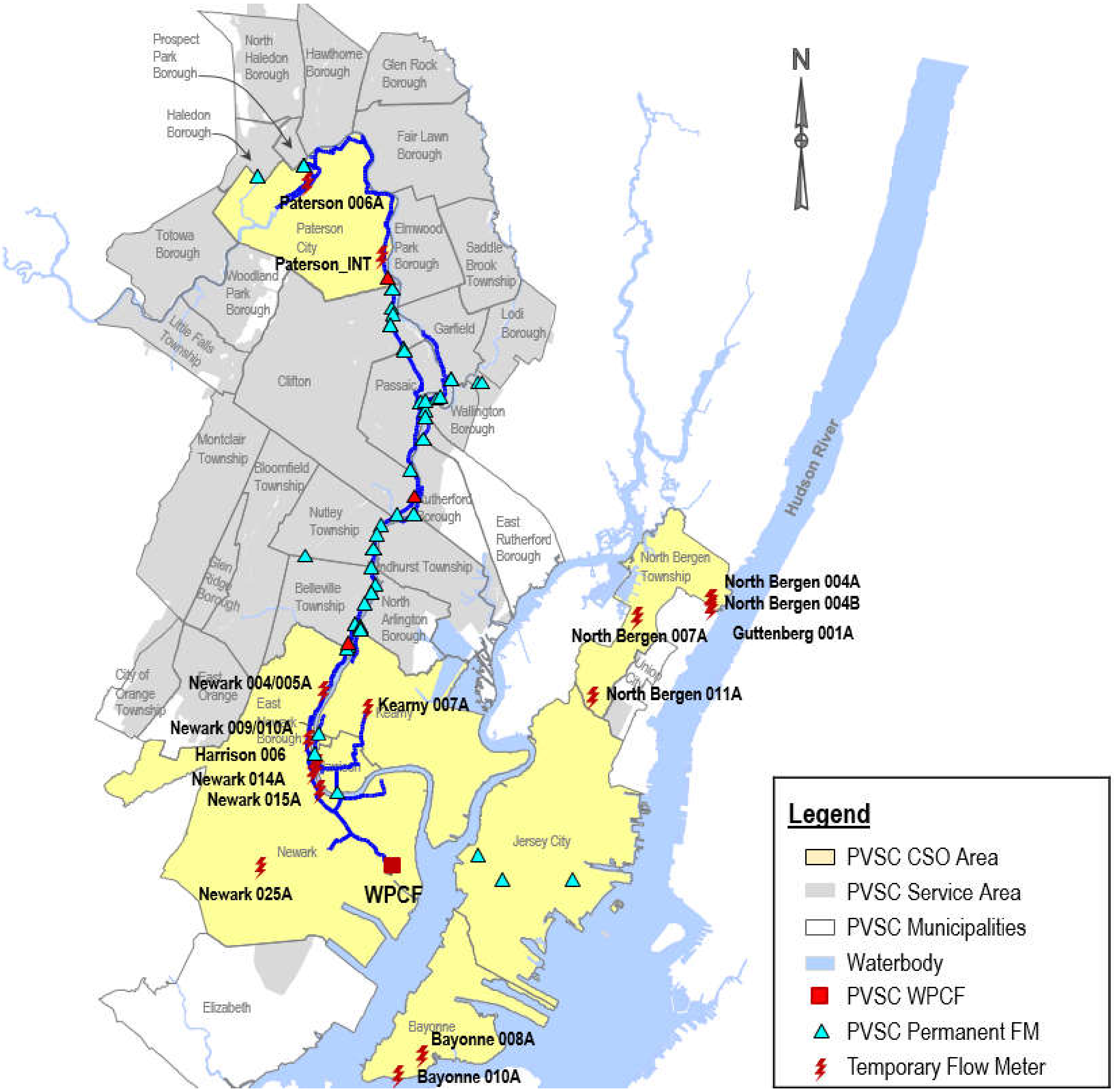


Figure E-1: Flow Meter Location

E.3 DRY WEATHER FLOW (DWF) ANALYSIS

A "dry weather" condition was defined as a period with no precipitation that begins 48 hours after the last wet weather event ends and lasts until the beginning of the next precipitation event (i.e. the rain gauge read a 0.01 inch value). Dry weather flow (DWF) periods based on this definition are illustrated in the hydrograph shown in **Figure E-2.**

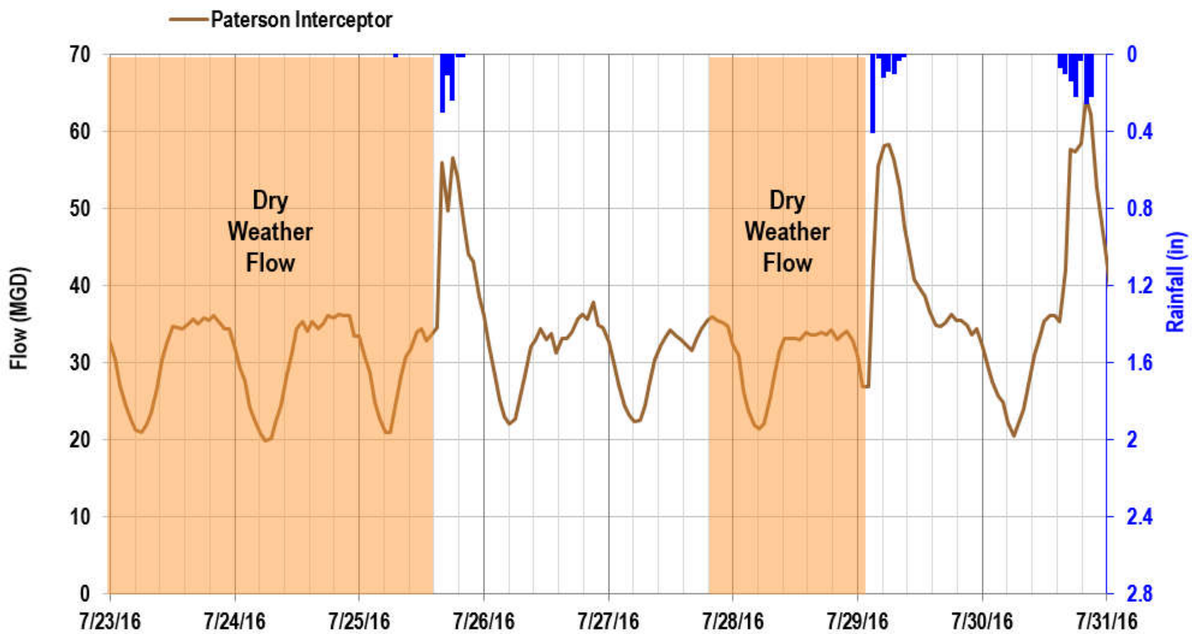


Figure E-2: Hydrograph showing Dry Weather Flow

Average dry weather flow was calculated by averaging the monitored flows from the dry weather periods identified in the rainfall data analysis. The overall and monthly DWFs for all monitoring sites were analyzed.

The DWFs for the monitoring period are also shown in the schematic in **Figure E-3**. Each value displayed next to each flow meter represents the DWF overall average (in MGD) for the monitoring period.

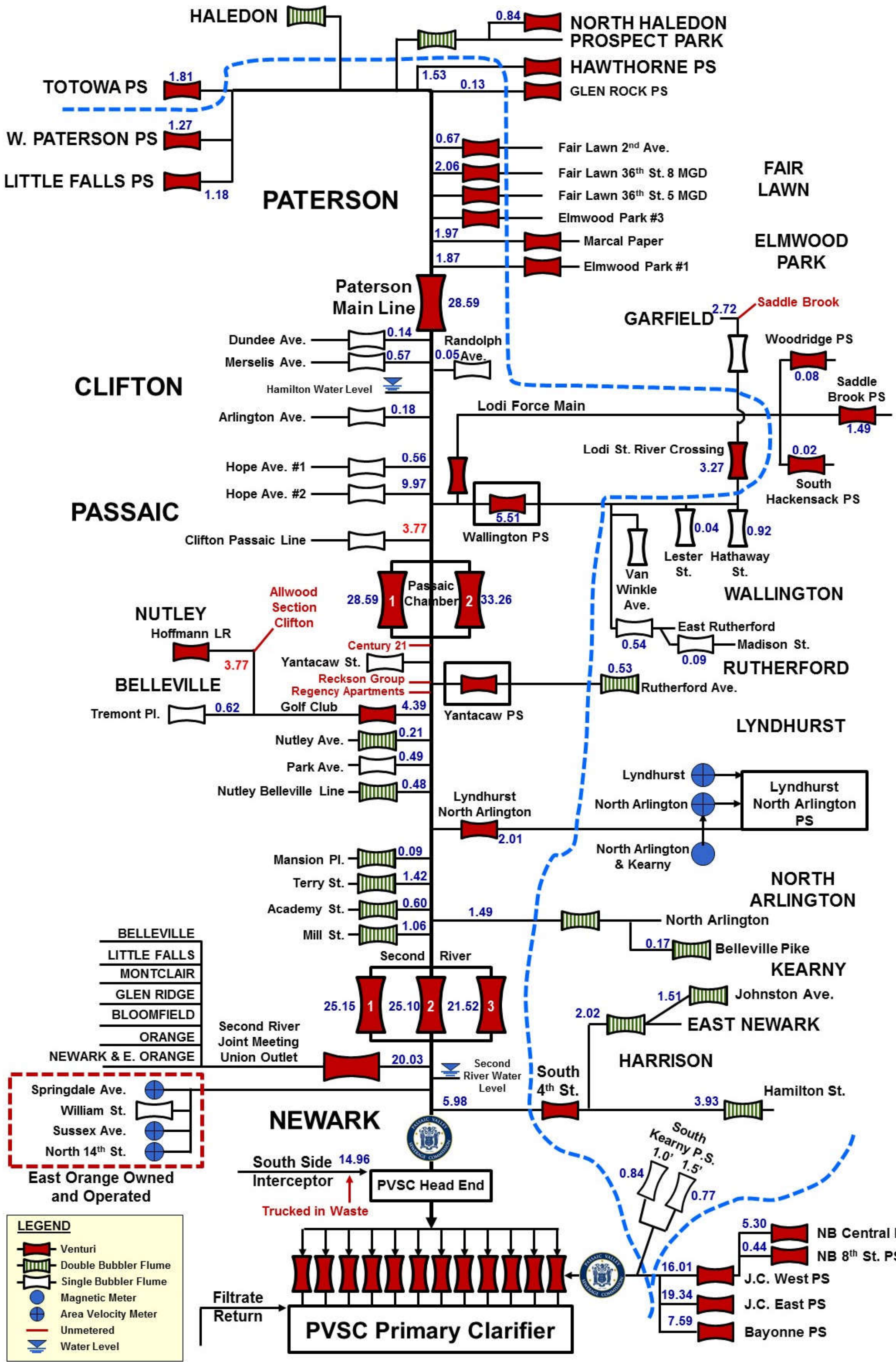


Figure E-3: Dry Weather Flow

GREELEY AND HANSEN
CDM Smith

The DWFs vary throughout the day, with the highest flows normally occurring around noon and the lowest rates between midnight and early morning. Flow data from the dry weather periods were used to develop a diurnal pattern for each flow meter. Diurnal patterns were analyzed for both weekdays and weekends. In the plot shown on **Figure E-4**, the weekend DWF peak and valley have a 3-hour lag compared to the weekday pattern. The weekday and weekend diurnal patterns were input into the model along with the overall annual average values discussed above.

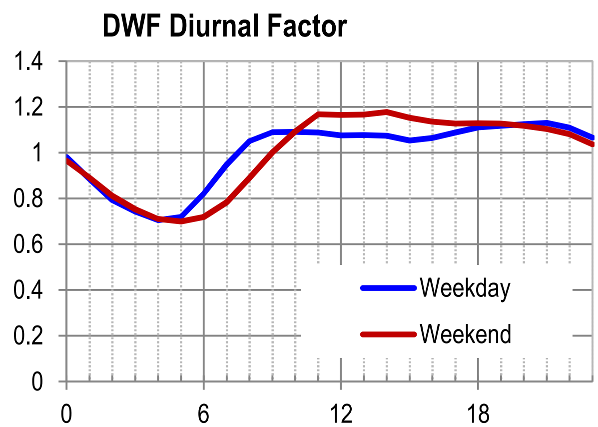


Figure E-4: Weekend and Weekday Dry Weather Flow Diurnal Pattern

E.4 WET WEATHER FLOW ANALYSIS

Wet weather flows are the combination of dry weather flows and additional flows that enter the system during wet weather conditions. The additional flows are from combined area surface runoff and RDII. Inflow normally occurs when rainfall enters the system through direct connections such as roof leaders, yard drains, catch basins, sump pumps, manhole covers and frame seals or cross connections with storm sewers. Inflow is usually recognized graphically by large magnitude, short duration spikes immediately following a rain event. Infiltration occurs during wet weather conditions when water enters a sewer system from the ground through means which include, but not limited to, deteriorated pipes, pipe joints, connections, or manholes. It is significantly influenced by the size and duration of the rainfall event. Infiltration is often recognized graphically by a gradual increase in flow after a wet weather event. The increased flow typically sustains for a short period after rainfall has stopped and then gradually drops off.

The peaking factor represents the ratio of the peak wet weather flow to the average dry weather flow. Usually, an hourly peaking factor is used to represent the wet weather peaking factor. Peaking factors were analyzed for each flow monitoring site. The peaking factors in the separate sewer area can be used to determine the extent of the RDII within a particular basin. **Figure E-5** is an example of the flow monitoring site showing an hourly peaking factor of approximately 3.0. This is within a reasonable peaking factor range for a sanitary sewer collection system. The flow increase shortly after the rainfall indicates immediate inflow into the collection pipes, and the long tail back to the base flow indicates infiltration occurrence at the site as well.

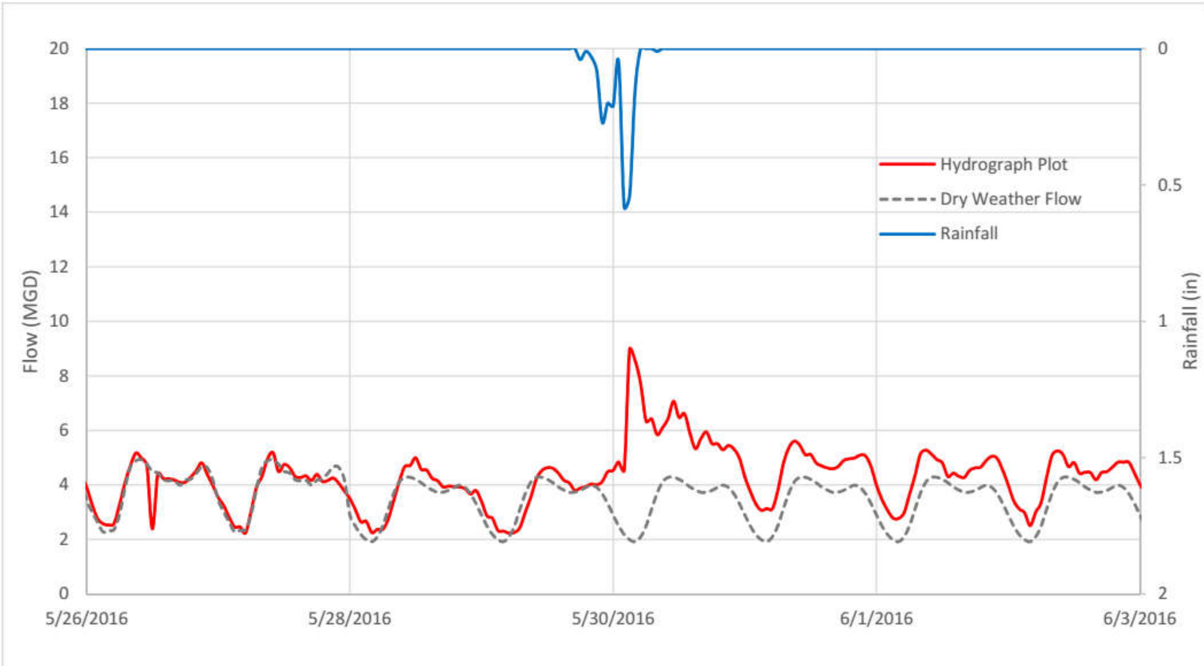


Figure E-5: Flow Monitoring Site Wet Weather Analysis (Example Plot)

E.5 WET WEATHER EVENT SELECTION FOR MODEL CALIBRATION AND VALIDATION FLOW ANALYSIS

Based on the rainfall and flow monitoring data analysis, the rainfall events shown in **Table E-4** were selected for model calibration and validation. The events were selected from the rain events that are shown in **Table E-2**. The calibration and validation events cover variations in terms of rainfall depth, intensity, duration and antecedent conditions.

Table E-2: Calibration and Validation Rainfall Events

Event Start	Event End	Duration (hr)	Depth (in)	Max Intensity (in/hr)	Average Intensity (in/hr)
7/25/16 16:05	7/25/16 18:50	2.75	1.81	1.68	0.66
5/29/16 23:50	5/30/16 5:20	5.50	1.60	1.09	0.29
7/29/16 0:20	7/29/16 8:35	8.25	0.85	0.42	0.10
7/31/16 8:35	7/31/16 22:35	14.00	0.69	0.49	0.05

E.6 SEWER FLOW MONITORING DATA SUMMARY

The majority of the flow meters measured flow, level and velocity data for each flow monitoring site at 5-minute intervals. The remaining flow meters measured the same parameters in 15-minute intervals. Metering data was analyzed for dry weather flows (DWF) and wet weather flows (WWF) for each monitoring site.

The DWF was ultimately used as inputs into the model. Overall average DWFs, average monthly DWFs, and weekday and weekend diurnal patterns were input into the model for each flow meter in the combined area. The WWF were used to calibrate the model output. Model data was compared side by side with metered data for each wet weather event for each flow meter.

E.7 RAINFALL MONITORING LOCATIONS AND ANALYSIS

Precipitation data for the flow monitoring period were obtained from NJ Weather, National Weather Service Automated Surface Observing System (NWS ASOS), and Citizen Weather Observer Program (CWOP). Rain gauge summary is provided in **Table E-3**.

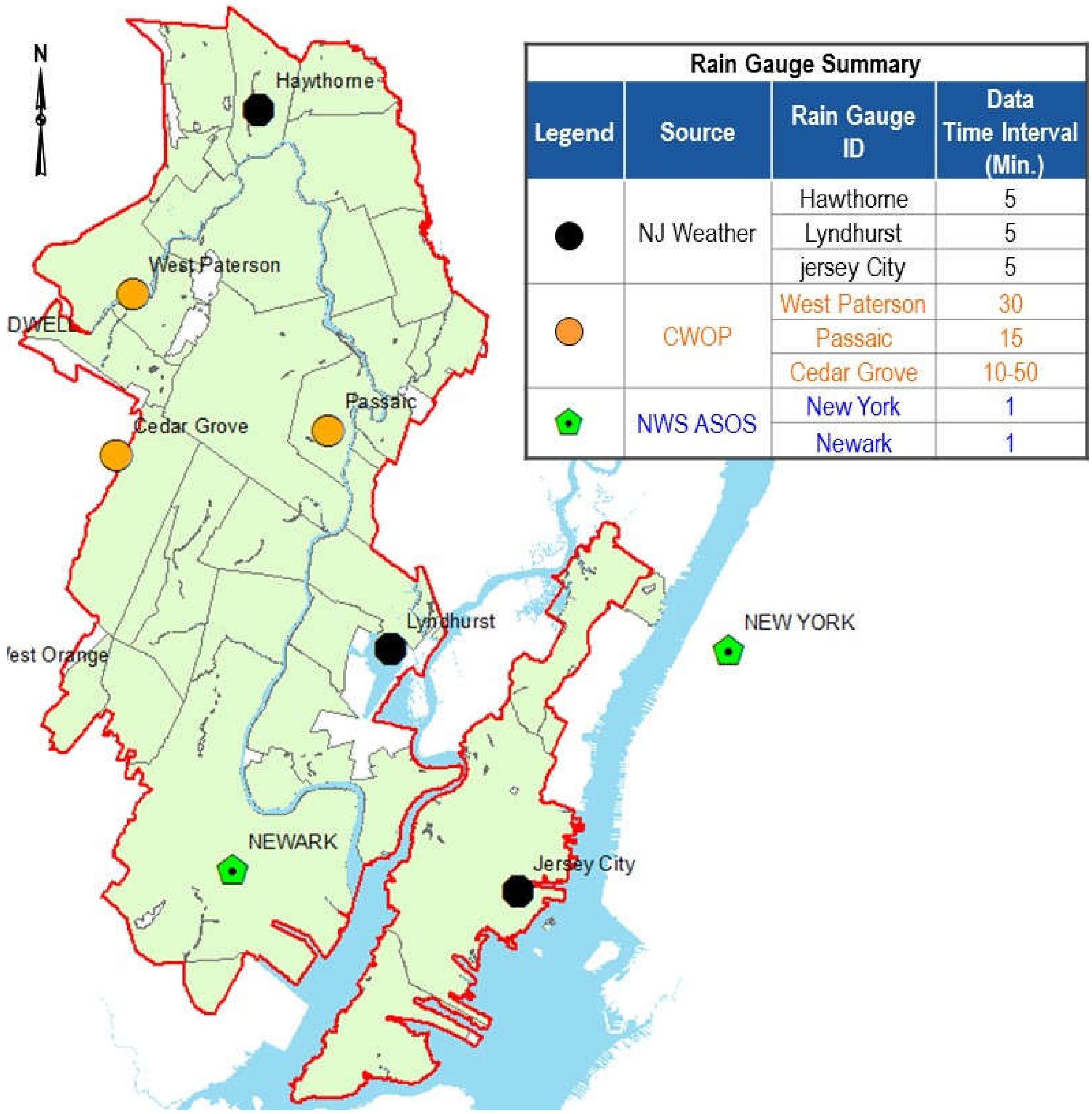
Table E-3: Rain Gauge Summary

Source	Rain Gauge ID	Data Time Interval (min)
NJ Weather	Hawthorne	5
NJ Weather	Lyndhurst	5
NJ Weather	Jersey City	5
CWOP	West Paterson	30
CWOP	Passaic	15
CWOP	Cedar Grove	10-50
CWOP	West Orange	10
NWS ASOS	Caldwell	1
NWS ASOS	New York	1
NWS ASOS	Newark	1

Figure E-6 shows the location of the rain gauges.

E.8 RAIN EVENT SUMMARY

The rainfall events were characterized by event start time, event end time, duration, rainfall depth, maximum intensity and average intensity. As an initial screening criterion, rainfall events with a minimum of 0.4 inches of rainfall were identified. Further screening based on requiring at least two dry days prior to the event resulted in the candidate events calibration and validation and are listed in **Table E-4**.



Rain Gauge Summary

Legend	Source	Rain Gauge ID	Data Time Interval (Min.)
● (black)	NJ Weather	Hawthorne	5
		Lyndhurst	5
		jersey City	5
● (orange)	CWOP	West Paterson	30
		Passaic	15
		Cedar Grove	10-50
⬟ (green)	NWS ASOS	New York	1
		Newark	1

Figure E-6: Rain Gauge Locations

Table E-4: Candidate Storm Events for Calibration

Rain Start	Rain End	Duration (hr)	Depth (in)	Max Intensity (in/hr)	Average Intensity (in/hr)
7/25/16 16:05	7/25/16 18:50	2.75	**1.81**	1.68	0.66
5/29/16 23:50	5/30/16 5:20	5.50	**1.6**	1.09	0.29
7/29/16 0:20	7/29/16 8:35	8.25	**0.85**	0.42	0.10
5/2/16 22:40	5/3/16 9:50	11.17	**0.7**	0.17	0.06
7/31/16 8:35	7/31/16 22:35	14.00	**0.69**	0.49	0.05
7/4/16 19:20	7/5/16 2:50	7.50	**0.63**	0.23	0.08
5/6/16 2:30	5/6/16 12:25	9.92	**0.6**	0.19	0.06
7/16/16 14:50	7/16/16 15:35	0.75	**0.56**	0.75	0.75
6/8/16 11:25	6/8/16 14:10	2.75	**0.49**	0.3	0.18
7/9/16 21:30	7/9/16 22:05	0.58	**0.48**	0.82	0.82
4/4/16 7:45	4/4/16 17:00	9.25	**0.43**	0.12	0.05

E.9 COLLECTION OF PVSC WATER RESOURCES RECOVERY FACILITY OPERATIONAL DATA

In addition to flow data collected from the flow meters located in the collection system, flow data from the PVSC WRRF influent flow meter was obtained for the same time period. A summary of the plant flow data is shown in **Figure E-7**.

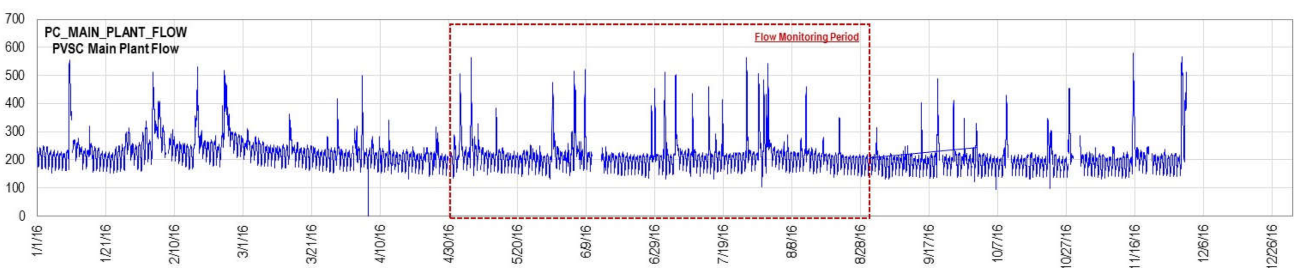


Figure E-7: PVSC WRRF Influent Flow

E.10 SUMMARY

The rainfall and flow monitoring data analysis was performed to provide adequate data for the development, calibration and validation of the H&H and Water Quality Models. Rainfall data was collected for rain gauges throughout the Model Area. The Newark Airport rain gauge was analyzed to determine which wet weather events would be used for model calibration. The flow meter data was analyzed based on the rainfall patterns and then input into the model as overall annual average DWF, average monthly DWFs, and weekday and weekend diurnal curves for each meter in the combined area. To calibrate the model, model-generated data was compared to the metered-data hydrographs for each wet weather event for each flow meter.

SECTION F - CHARACTERISTICS OF THE RECEIVING WATERS

Characteristics of the receiving waters include description of the receiving waters designated use, shoreline characteristics, identification of the waters on the impaired waters of NJ and a summary of the sensitive areas within the receiving water. The USEPA CSO Control Policy Guideline requires that highest priority is given to CSO's that discharge to sensitive areas.

F.1 RECEIVING WATERS OVERVIEW

Major receiving waters impacted from PVSC service area combined sewer overflows include the Passaic River, Hackensack River, Newark Bay, Upper New York Bay, Hudson River, Kill Van Kull, Raritan River and Raritan Bay, as well as their tributaries. The NJDEP has categorized these receiving waters into Watershed Management Areas (WMA) 1 through 20 and refers to these designations in the 303(d) list of impaired water.

F.1.1 CSO Receiving Waters

CSO receiving waters are water bodies that either a CSO discharges into, or receive flow from tributaries with CSOs. The receiving waters include the combined sewer service area of the PVSC Sewer District and expands from this service area to include all receiving and adjacent downstream waters that may be potentially affected by CSOs from the various combined sewer service areas of the NJ CSO Group. PVSC CSO Sewer District receiving waters include the Passaic River, Hudson River, Newark Bay, Upper New York Bay, Hackensack River, Kill Van Kull, as well as their tributaries. All of the CSO outfalls and the waterbodies into which they discharge are listed in **Table D-2**.

F.1.2 Summary of Impacted Drainage Basins

The receiving waters and their tributaries belong to drainage basins that are impacted by CSO discharges. Drainage basins, or watersheds, are areas that are separated by drainage divides and within a watershed, all surface water drains to a single outlet such as a river. The impacted watersheds within PVSC Sewer District are listed in **Table F-1**. The watersheds are also shown with the QAPP Part 1 and Part 2 areas from the "System Characterization and Landside Modeling Program Quality Assurance Project Plan (QAPP)," which have been previously approved by NJDEP areas in **Figure F-1**.

Table F-1: Watersheds Affected by CSO Discharges

Watershed Name	Area (sq mi)
Hudson River	5
Passaic River Lower (Saddle to Pompton)	46
Hackensack River (below and including Hirschfeld Brook)	19
Passaic River Lower (Newark Bay to Saddle)	52
Elizabeth River	2
Newark Bay / Kill Van Kull / Upper NY Bay	25

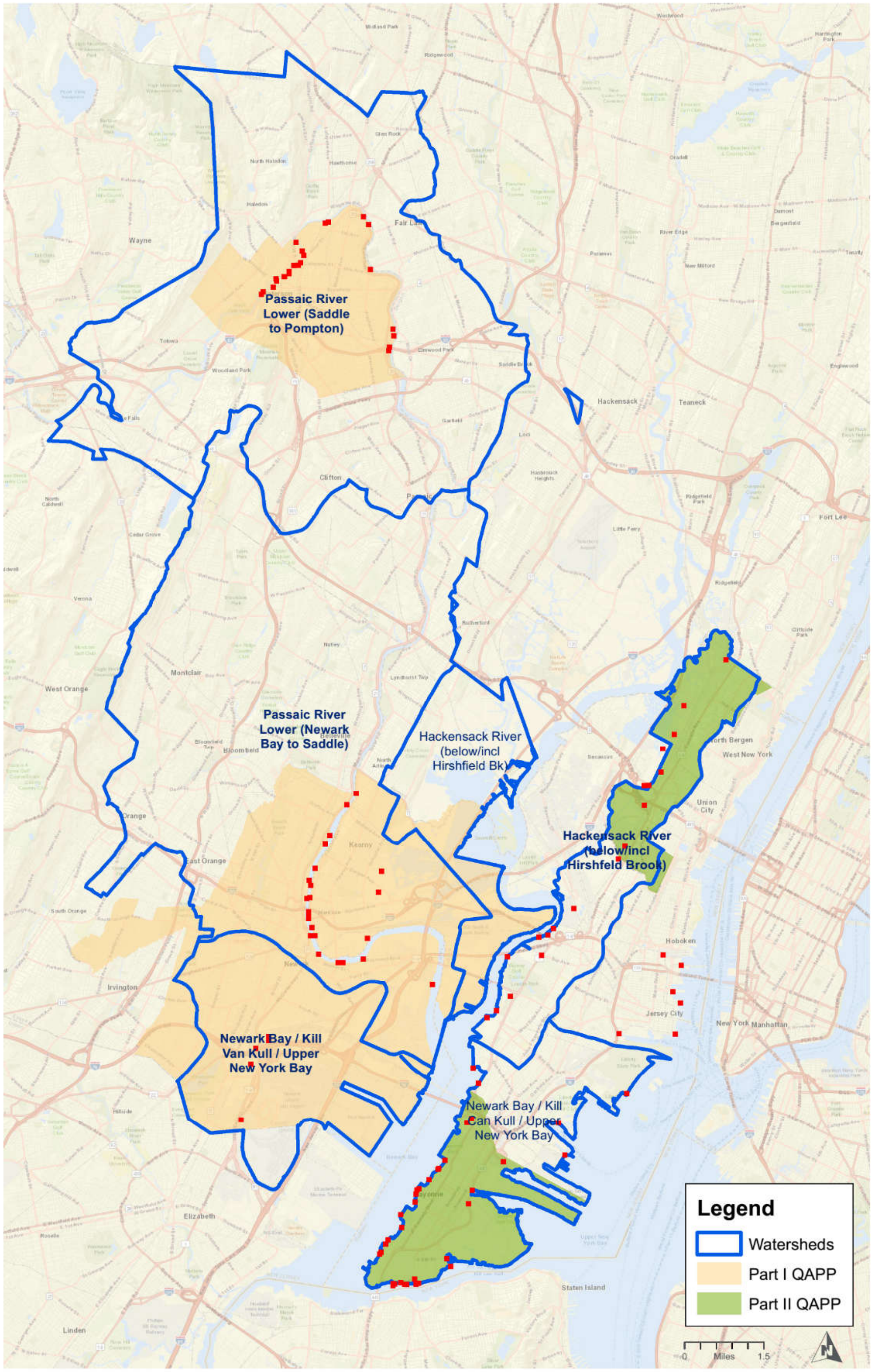


Figure F-1: PVSC Sewer District Watersheds

F.2 POLLUTANTS OF CONCERN IN THE RECEIVING WATERS

F.2.1 Summary of the Identified POCs for Each Receiving Water

Three (3) POCs were determined to apply to each of PVSC Sewer District's four receiving waters. These three POCs are parameters typically associated with CSO discharges. The concentrations of these identified POCs in the receiving waters have been further investigated through the receiving water quality monitoring and modeling, subsequently described in Sections E, G, H and I of this report. The NJDEP determined POCs for each of the receiving waters relative to the PVSC CSO sewer district are listed below:

- Passaic River
  - Fecal Coliform
  - Escherichia coli (E. coli) (fresh water)
  - Enterococcus
- Newark Bay
  - Fecal Coliform
  - E. coli (fresh water)
  - Enterococcus
- Upper New York Bay
  - Fecal Coliform
  - E. coli(fresh water)
  - Enterococcus
- Hackensack River
  - Fecal Coliform
  - E. coli (fresh water)
  - Enterococcus

F.3 RECEIVING WATER USE DESIGNATIONS AND APPLICABLE WATER QUALITY STANDARDS

F.3.1 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

The New Jersey Integrated Water Quality Monitoring and Assessment Report (303(d) list) is a catalog of the impaired waters throughout the state of New Jersey. More information about the 303(d) list can be found in Section B.2.4

F.3.2 Interstate Environmental Commission (IEC) Water Quality Regulations

The Interstate Environmental Commission (IEC) is an air and water pollution control agency that serves the Interstate Environmental District within the states of New York, New Jersey, and Connecticut. The Commission's goal is to protect the environment and assure compliance with and enforcement of its Water Quality Regulations. For more information about IEC Regulations, see Section B.2.5.

F.3.3 New Jersey Administrative Code

NJAC Section 7:9B Surface Water Quality Standards lists the classifications, designated uses, and water quality criteria for the all New Jersey water bodies. For more information about the NJAC, see Section B.2.6.

F.4 PASSAIC RIVER

F.4.1 Watershed Drainage Basin

The Passaic River basin consists of three areas referred to as the Upper Basin (Highlands), Central Basin and the Lower Basin (Lower Valley) and drains approximately 935 square miles of Northern New Jersey and Southern New York State. The NJDEP has designated the Upper and Mid Passaic River, Whippany and Rockaway as Watershed Management Area 6 (WMA 6) and the Lower Passaic River and Saddle as Watershed Management Area 4 (WMA 4). Passaic River basin is characterized by extensive suburban development of which relies upon ground water sources for water supply. The Passaic River basin lies in portions of Morris, Somerset, Sussex and Essex Counties and includes the Upper and Middle Passaic River, Whippany River and Rockaway River Watersheds. The portion of the Passaic River Basin which overlaps the PVSC service area is mainly in the lower basin and extends from the City of Paterson to the City of Newark. See the Passaic River Watershed map shown below in **Figure F-2.**

Frank's Creek, Second River, Third River, Pompton River, and Saddle River are tributaries of the Passaic River. Generally CSO regulator outfalls located in Paterson, Newark, Harrison, Kearny and East Newark are permitted to discharge to the Passaic River. Several CSOs regulator outfalls located in Kearny are permitted to discharge to Frank's Creek.

F.4.2 Physical Characteristics

The Lower Passaic River begins at the Pompton River confluence and continues downstream eventually reaching the Newark Bay. The Lower Passaic River and its tributaries, including the Saddle River, has a drainage area of about 180 square miles. The Lower Passaic River Watershed lies within portions of Passaic, Essex, Hudson, Morris, and Bergen Counties.

All 129 square miles of the Lower Passaic River Watershed are primarily urban/suburban. The section of the Lower Passaic River within the urban/suburban area has poor water quality conditions due to numerous point sources, significant nonpoint source contributions, and high sediment oxygen demands, (State of New Jersey, 2014). The Lower Passaic River Watershed's water quality conditions are affected by a number of hazardous waste sites and contamination issues that have resulted from a long history of industrialization, (State of New Jersey, 2014).

The primary aquatic habitats of the lower Passaic River are intertidal mudflats and subtidal bottom (Ianuzzi, 2004). The intertidal mudflats and their associated shallow-water subtidal areas are primary habitats for estuarine organisms, providing the only available foraging habitat for fish, blue crab, and waterbirds.

Figure F-2: Map of the Passaic River Basin Retrieved from https://passaicriver.org/passaic-river-basin/

F.4.3 Hydrodynamics

The Passaic River stretches approximately 80 miles from Mendham, NJ to Newark Bay. The Passaic River Basin drains approximately 935 square miles, 85% of which are located in New Jersey and the rest in New York. The project study area includes the last nine miles of the Upper Passaic River from just upstream of Paterson, NJ to the Dundee Dam in Garfield, NJ, as well as the Lower Passaic River. The Upper Passaic River includes water withdrawals by the North Jersey District Water Commission and the Passaic Valley Water Commission. The Upper Passaic River also includes the Great Falls in Paterson, NJ. The Lower Passaic River is the 17-mile tidal stretch of the Passaic River from the Dundee Dam to its confluence with Newark Bay. Most of the freshwater originates from upstream of the Dundee Dam with an annual average discharge rate of about 1,200 cfs (TSI, 2003). There are, however, three major tributaries to the Lower Passaic River that bring additional fresh water river downstream of the Dundee Dam. These are:

- Saddle River (99 cfs)
- Third River (about 21 cfs)
- Second River (18 cfs)

Four other tributaries, McDonald Brook, Frank Creek, Lawyer's Creek, and Plum Creek have also been identified historically as contributing freshwater inflow to the Lower Passaic River. However, these tributaries are now urbanized tributaries, and now receive freshwater inflows via CSO and / or Stormwater Outfalls (SWO) inputs. The combined flow of the three major tributaries (Saddle River, Third River, and Second River) is estimated to represent less than 10% of the total flow at the mouth of the estuarine section of the combined Lower Passaic River/Hackensack River system.

CSOs, as well as SWOs, also contribute to the inflow of freshwater in the Passaic River. No WRRF outfalls are located in the Lower Passaic River. However, the Northwest Bergen County Utilities Authority discharges Ho-Ho-Kus Brook, which flows to the Saddle River.

The waters of the Lower Passaic River are also influenced by semidiurnal tides reaching a mean tidal range of about 5 ft. Density stratification is prevalent in the Lower Passaic River causing a distinct reversal of residual currents between top and bottom layers of the water column. Historical salinity data indicates that salt can travel upstream about 10 miles from the mouth of Passaic River during conditions of low river inflows. The salt front can be pushed out of the Lower Passaic River under moderately high river flows, i.e., 100 m^3/sec or 3,500 cfs (Chant, personal communication). Field studies conducted by TSI in 1995-6 and Rutgers University in 2004 indicate that intra-tidal variations in surface and bottom salinities near the mouth of the Lower Passaic River can reach as high as 10 ppt (parts per thousand).

F.4.4 Shoreline Characteristics

The Lower Passaic River (downstream of the Dundee Dam) has a mix of bulkheaded industrial and natural shorelines. Extensive parkland line the River in Bergen County. Natural vegetation also lines the freshwater sections along Dundee Lake and sections in Paterson and further upstream. Vegetated wetland comprises approximately one acre of the lower six miles of shoreline of the Lower Passaic River.

The natural shoreline of the lower six miles of the Lower Passaic River has been industrialized and is mostly lined with buildings and parking lots. Approximately 52 percent of the lower six miles of the Passaic River has been bulkheaded; another 30 percent of the shoreline is riprap, (New Jersey, 2014). Weedy vegetation lines the shoreline in a few remaining riparian areas. In mudflats reeds grow in abundance. Trees and scrub-shrubs grow in higher elevations. Ruderal plants such as tree of heaven and goldenrod are found throughout the area (Ianuzzi, 2004).

F.4.5 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

The Passaic River is listed on the 303 (d) list as being impaired for the following pollutants:

- Arsenic
- Benzo(a)pyrene (PAHs)
- Cause Unknown
- Chlordane in Fish Tissue
- DDT and its metabolites in Fish Tissue
- Dieldrin
- Dioxin (including 2, 3, 7, 8-TCDD)
- Escherichia coli
- Heptachlor epoxide
- Mercury in Fish Tissue
- Oxygen, Dissolved
- PCBs in Fish Tissue
- pH
- Phosphorus (Total)
- Total Suspended Solids (TSS)

F.4.6 Designated Uses and Water Quality Criteria from NJ Code

NJAC Section 7:9B Surface Water Quality Standards lists the Passaic River as FW2-NT in the Paterson reach, FW2-NT/SE2 in the Little Falls reach, and SE3 in the Newark reach at the Second River. The classification FW2-NT refers to a fresh water non trout water body. SE2 and SE3 both refer to saline estuarine water bodies. Classifications along with designated uses, indicator bacteria and their criteria are shown in **Table F-2** below.

Table F-2: NJ Administrative Code Regarding the Passaic River

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 mL)
FW2	Primary Contact	E. coli	126 GM, 235 SSM
SE2	Secondary Contact	Fecal Coliform	770 GM
SE3	Secondary Contact	Fecal Coliform	1500 GM

F.4.7 Classification and Water Quality Regulations from the IEC

The IEC classifies the mouth of the Passaic River as Class B-1. For more information regarding the IEC standards for Class B-1 water bodies, see Section B.2.4.

F.5 NEWARK BAY

F.5.1 Watershed Drainage Basin

Newark Bay is a tidal bay and is located at the confluence of the Passaic and Hackensack Rivers at the northern end of the bay. Newark Bay is connected to the Kill Van Kull and Arthur Kill at the southern end adjacent to Staten Island. The Kill Van Kull is a tidal strait which connects the Newark Bay to the Raritan Bay and lies between Staten Island and the City of Bayonne. The Arthur Kill links the Newark Bay with the Lower New York Bay. Other tributaries of Newark Bay include the Elizabeth River, the Arthur Kill, and the Peripheral Ditch, Queen Ditch and Great Ditch. The Upper New York Bay is also a tidal bay and is located between New York City and Jersey City. The Hudson River flows into the northern end of the Upper Bay. Newark Bay, Upper New York Bay, Kill Van Kull and Arthur Kill are all considered part of the NJDEP Arthur Kill Watershed Management Area 7.

City of Bayonne CSO regulator outfalls are permitted by NJDEP to discharge to the Newark Bay, Kill Van Kull and the Upper New York Bay. A few CSO outfalls located in the City of Newark are permitted to overflow to the Peripheral Ditch and Queen Ditch. See **Figure F-3** below for location of the CSO Outfalls in the Newark Bay area.

F.5.2 Physical Characteristics

The Newark Bay is approximately 6 miles long extending in the north south direction and varies in width from one-half mile to 1.2 miles. Newark bay shipping channels range in depth from 35 to 50 feet at Mean Low Low Water tide (MLLW). The bay area aside from the channel range in depth from 0 at the shoreline to approximately 11 to 15 feet at MLLW. The Kill Van Kull is a narrow straight channel that is approximately 3 miles long extending in the east west direction and 1000 feet wide. The shipping channel depth through the Kill Van Kull is approximately 50 feet at MLLW. The Arthur Kill is a 10 mile channel extending in the north south direction and runs along the west side of Staten Island. The Arthur Kill shipping channel depth ranges from 30 to 50 feet at MLLW.

F.5.3 Hydrodynamics

The Passaic River along with the Hackensack River and Newark Bay is one of the most complex estuarine systems in the United States. The system is connected to two tidal straits, named the Kill van Kull and the Arthur Kill. These straits connect Newark Bay and the Passaic and

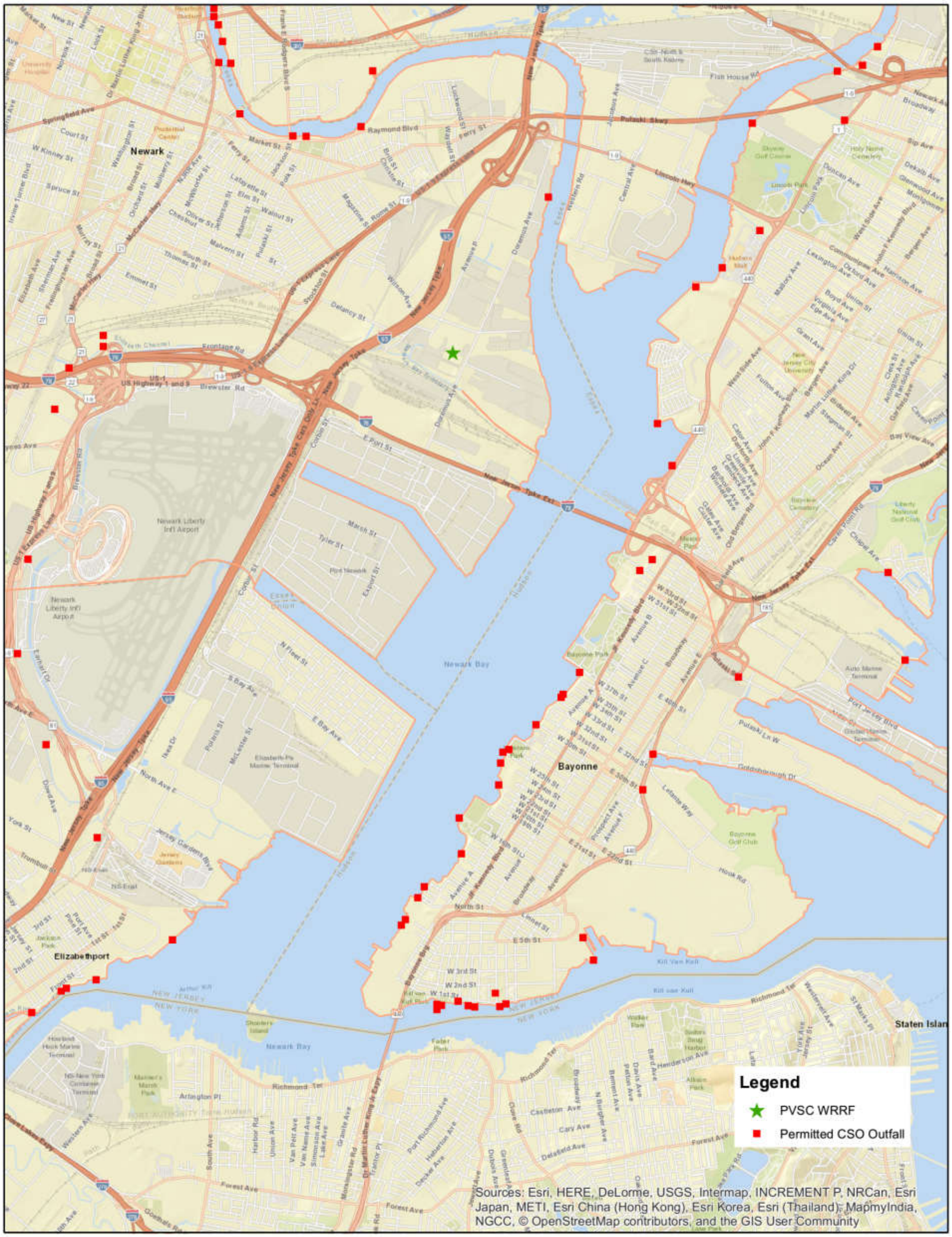


Figure F-3: The Newark Bay

Hackensack Rivers with the Upper New York Bay and Raritan Bay, through which tides, originating in the Atlantic Ocean, enter the system. The bathymetry of the Passaic-Hackensack-Newark Bay system is characterized by deep shipping channels along the center of both the Arthur Kill and the Kill van Kull, as well as the west side of Newark Bay through the center of both the Lower Passaic and Hackensack Rivers, with shallower side banks. The USACE maintains the navigability of the channels in order to support New York-New Jersey Port operations. The shipping channels, maintained by the USACE to facilitate the movement of container ships in and out of Newark Bay, added additional complexity to the dynamics of the system. The shipping channels in Newark Bay and the Kills are relatively deep (35 - 50 ft). The near-shore depths vary significantly. The shipping channels play an important role in transporting saline water from the ocean into the system.

The hydrodynamics of the Passaic-Hackensack-Newark Bay system is predominantly controlled by three forcing mechanisms, freshwater flows, tides, and winds. Two major sources of freshwater inflows, the Passaic and Hackensack Rivers, contribute to the salinity gradients in the system. By far, the largest freshwater contribution is from the Passaic River. The long-term (1983-2003) daily average flow measured at Little Falls is about 29 m^3/sec (1,000 cfs) and the maximum flow during this 21-year period was approximately 500 m^3/sec (18,000 cfs) in April 1984. In contrast the average flow in the Hackensack River is only 1.6 m^3/s (56 cfs) and a maximum flow of approximately 158 m^3/s (5,500 cfs) was measured in September 1999 during Hurricane Floyd. The salinity dynamics in the system are mostly controlled by the freshwater flows from the Passaic and Hackensack Rivers and the saltier ocean waters that enter the system through the Kill van Kull and the Arthur Kill. During most low to moderate flow periods, the salinity front stays within upper Newark Bay and the Lower Passaic and Hackensack Rivers. Salinity is, in general, higher during the time of low freshwater flow and is also more uniform both vertically and horizontally throughout the system than during the time of high freshwater flow. Freshwater flows emanating from the Passaic River stay along the western edge of Newark Bay, creating cross channel salinity gradients (Pence, 2004). The deep shipping channels in the system act as conveyances of denser and saltier ocean water to upper Newark Bay and to the Lower Passaic and Hackensack Rivers.

Tidal influence has significant importance within the Passaic-Hackensack-Newark Bay estuarine system. A harmonic analysis of tidal elevation data measured at Bergen Point, which is at the entrance to Newark Bay, suggests that the semi-diurnal constituents (M2 and S2) dominate the system. A spectral analysis of the tidal elevations also indicated that maximum variance occurred at an interval of approximately 12.4 hours, suggesting a dominant semi-diurnal tidal signal. The resultant tidal harmonic constituents are provided in **Table F-3**. The table indicates that the study area has predominant semi-diurnal tides.

Table F-3: Characteristics of Principal Tidal Constituents in Newark Bay

Constituents	Period (Hrs)	Amplitude (m)	Phase (deg)
O_1	25.82	0.05	107.1
K_1	23.93	0.10	108.6
M_2	12.42	0.73	233.7
S_2	12.00	0.14	263.8
N_2	12.66	0.16	220.4

Tidal currents in Newark Bay and in the Passaic and Hackensack Rivers are found to be moderate, with maximum amplitudes of 0.5 m/sec. Most of the time, the surface and bottom tidal currents are of equal magnitude and are in phase in Newark Bay. However, during high-flow periods the surface currents, directed towards the ocean (ebb currents), become much stronger than the bottom currents, indicating the presence of strong vertical shear (Pence, 2004). During high freshwater flow, classical two-layer estuarine circulation is observed during flood tides, with surface currents flowing seaward and bottom currents flowing upstream. The net flow along the side banks is downstream, with an increased magnitude under higher freshwater flow conditions.

Strong and persistent wind events in Newark Bay can have a strong effect on the circulation in the estuary, and in some extreme cases can disrupt the normal pattern of estuarine circulation. Modeling analysis (Pence, 2004, Pecchioli et al., 2006) suggests that strong winds from the west will flush water and water borne constituents from Newark Bay out through the Kill van Kull, with weaker flow in through the Arthur Kill. Model computations indicate that this flow pattern changes direction when strong winds blow from the east, i.e., flow enters the Kill van Kull from the upper portion of New York/New Jersey Harbor and then enters Newark Bay (Pecchioli et al., 2006).

F.5.4 Shoreline Characteristics

The Newark Bay shoreline has been industrially developed with approximately two-thirds of the shoreline consisting of riprap and bulkhead.

- Bulkhead - 40%
- Mixed Intertidal - 10%
- Riprap - 30%
- Vegetation - 20%

Most of the western shoreline of Newark Bay is bulkheaded and lies in industrial areas. In 1958, the Port Authority dredged the Elizabeth Channel and created the Elizabeth Marine Terminal on the northwest side of Newark Bay. Most of the eastern shoreline is riprap or bulkheaded and lies in residential and recreational areas. At the south end of Newark Bay, near Staten Island, is Shooters Island, which is a 43-acre bird sanctuary with riprap shoreline. The south side of

Newark Bay, on the north side of Staten Island, is wetlands. There is a small remaining plant community located in the upland and wetland area as a reflection of these disturbed bulkheaded conditions. Some of the area along the shoreline is used for fishing.

F.5.5 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

The Newark Bay is listed on the 303 (d) list as being impaired for the following pollutants:

- Benzo(a)pyrene (PAHs)
- Cause Unknown
- Chlordane in Fish Tissue
- DDT and its metabolites in Fish Tissue
- Dieldrin
- Dioxin (including 2, 3, 7, 8-TCDD)
- Heptachlor epoxide
- Hexachlorobenzene
- Mercury in Fish Tissue
- PCB in Fish Tissue
- Phosphorus (Total)

F.5.6 Designated Uses and Water Quality Criteria from NJ Administrative Code

NJAC 7:9B Surface Water Quality Standards lists the portion of the Newark Bay north of an east-west line connecting Elizabethport with Bergen Pt., Bayonne up to the mouths of the Hackensack and Passaic Rivers as SE3. SE3 refers to a saline estuarine water body. Classifications along with designated uses, indicator bacteria and their criteria are shown in **Table F-4** below.

Table F-4: NJAC Regarding the Newark Bay

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 mL)
SE3	Secondary Contact	Fecal Coliform	1500 GM

F.5.7 Designated Zone and Water Quality Regulations from the IEC

The IEC classifies the Newark Bay as Class B-2. For more information regarding the IEC standards for Class B-1 and B-2 water bodies, see Section B.2.4.

F.6 UPPER NEW YORK BAY

F.6.1 Watershed Drainage Basin

The Upper New York Bay is a tidal bay and is located between New York City and Jersey City at the confluence of the Hudson and East Rivers.

CSOs regulators located in Guttenberg and northern part of Bayonne are permitted by NJDEP to discharge to the Hudson River and the Upper New York Bay area. See **Figure F-4** below for location of the CSO Outfalls in the Upper New York Bay Area.

F.6.2 Physical Characteristics

The Upper New York Bay is approximately 7 miles long extending in the north south direction and varies in width from 1 mile to 5 miles. The Upper New York Bay is connected to the Lower New York Bay by the Narrows. The Upper New York Bay has a maximum shipping channel depth of 50 feet. The Upper New York Bay includes Ellis Island, Liberty Island and Governors Island.

F.6.3 Hydrodynamics

Upper New York Bay is bordered by the New York City boroughs of Manhattan, Brooklyn and Staten Island and the New Jersey municipalities of Jersey City and Bayonne. The hydrodynamics within the bay are complicated due to its interconnectedness with several waterbodies. It receives freshwater from the Hudson River to the north, and is connected with the East River, Kill Van Kull, and the New York Bight (Atlantic Ocean). The channel of the Hudson as it passes through the bay is called the Anchorage Channel and is approximately 50 feet deep in the midpoint of the bay. The drainage area for the Hudson River is approximately 14,000 square miles, with 8,090 square miles in the non-tidally affected area above the Troy Dam near Green Island, NY. USGS gage 01358000 at Green Island, NY measures an average flow of approximately 14,500 cfs, with a maximum estimated flow of 215,000 cfs occurring on March 19, 1936. Additional freshwater is added from the drainage area below the dam.

The combination of freshwater flow from the Hudson River, saltwater flow from the Atlantic Ocean, and tidal exchange can create a two layer flow with freshwater at the surface leaving the bay to the south, and saltwater flow at the bottom entering the bay through the deep channel. The salt front (100 milligrams per liter of chloride) ranges from below Hastings-on-Hudson to New Hamburg during most years, but can move as far north as Poughkeepsie during periods of drought.

F.6.4 Shoreline Characteristics

The Upper New York Bay shoreline has been bulkheaded for industrial development including shipping and ferry terminals, residential use and park and recreational use. Several islands are located in the Upper New York Bay including Governors Island, Liberty Island, Ellis Island, and Robbins Reef. A small portion of the shoreline in is riprap and natural shoreline.

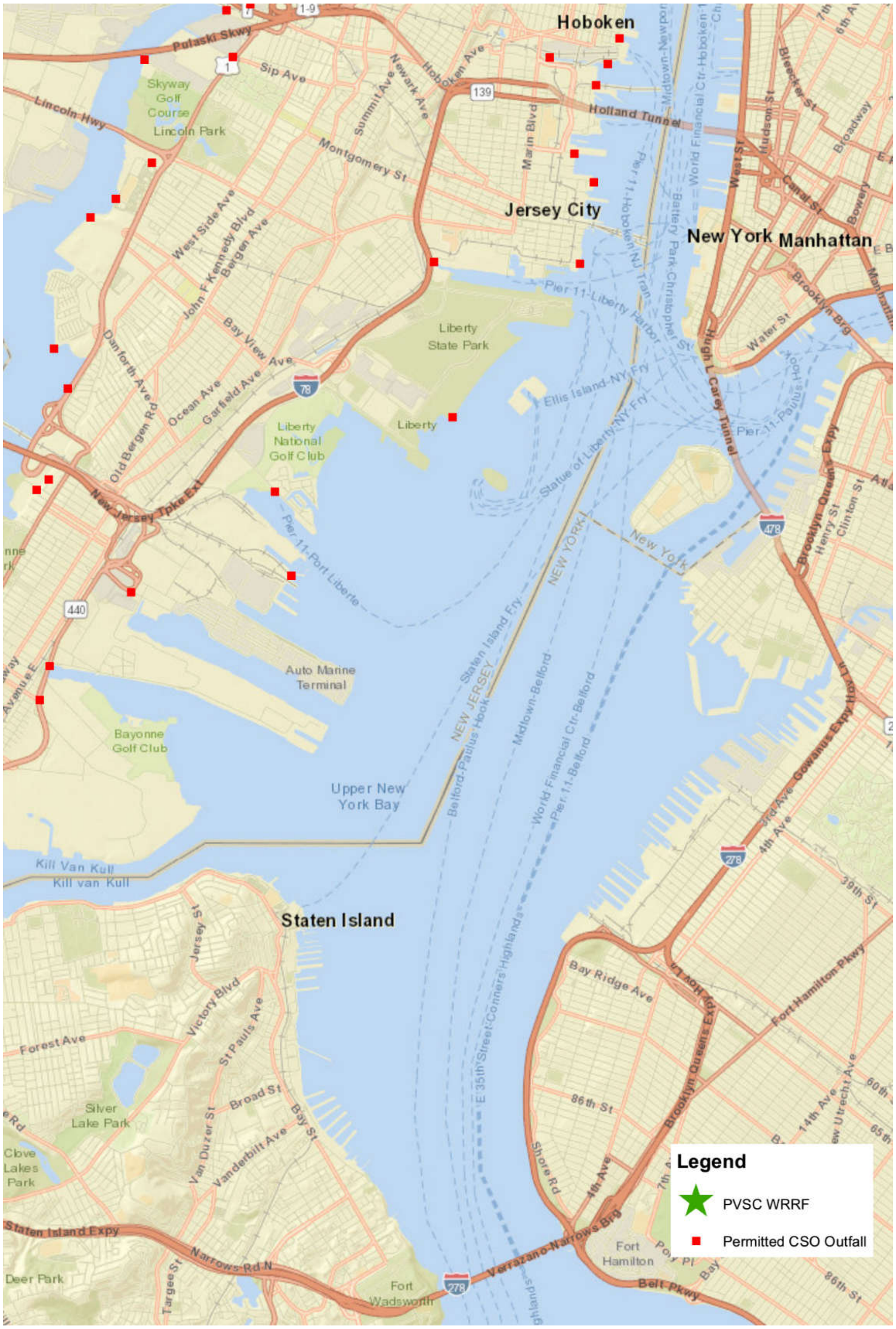


Figure F-4: The Upper New York Bay

F.6.5 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

The Upper New York Bay is listed on the 303 (d) list as being impaired for the following pollutants:

- Benzo(a)pyrene (PAHs)
- Cause Unknown
- Chlordane in Fish Tissue
- DDT and its metabolites in Fish Tissue
- Dieldrin
- Dioxin (including 2, 3, 7, 8-TCDD)
- Heptachlor epoxide
- Hexachlorobenzene
- Mercury in Fish Tissue
- PCB in Fish Tissue
- Phosphorus (Total)

F.6.6 Designated Uses and Water Quality Criteria from NJ Administrative Code

The Upper New York Bay is included in the NJAC as the Hudson River and saline portions of New Jersey tributaries from the confluence with the Harlem River, New York to a north-south line connecting Constable Hook (Bayonne) to St. George (Staten Island, New York) as SE2. SE2 refers to a saline estuarine water body. Classifications along with designated uses, indicator bacteria and their criteria are shown in **Table F-5** below.

Table F-5: NJAC Regarding the Newark Bay

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 mL)
SE2	Secondary Contact	Fecal Coliform	770 GM

F.6.7 Designated Zone and Water Quality Regulations from the IEC

The IEC classifies the Upper New York Bay (Hudson River) as Class B-1 and the Newark Bay as Class B-2. For more information regarding the IEC standards for Class B-1 and B-2 water bodies, see Section B.2.4.

F.7 HACKENSACK RIVER

F.7.1 Watershed Drainage Basin

The Hackensack River is considered part of the NJDEP Watershed Management Area 5 (WMA 5) which has a drainage area of over 165 square miles. There are three watersheds in WMA 5 including the Hackensack River, Hudson River and the Pascack Brook. The majority of the lower Hackensack River is tidal marsh known as the Hackensack Meadowlands. Tributaries of the Hackensack River include Cromakill Creek, Bellman's Creek, and Penhorn Creek.

CSOs regulators located in North Bergen Township are permitted by NJDEP to discharge to the Cromakill Creek and Bellman's Creek. See **Figure F-5** below for location of the CSO Outfalls in the Hackensack River Area.

F.7.2 Physical Characteristics

The Hackensack River watershed contains tidal marshes known as the Hackensack Meadowlands District. Seven hundred plant and animal species live in the Meadowlands, including several rare and endangered species. The Hackensack River watershed is the most populated out of all the CSO receiving watersheds outlined in this report. Although half of the land is still not developed, more than one third has been developed into dense residential areas. The remaining developed land is used for commercial/industrial activity.

Point sources of pollution such as hazardous waste and Superfund sites are known to contaminate the surface waters in the Hackensack River watershed. Due to contamination, it is prohibited to consume or sell striped bass and blue crabs.

Nonpoint sources of pollution mainly affect water quality. Examples of nonpoint sources in the area include extensive urban/suburban development and landfills. Runoff from construction sites, impervious surfaces, landfill leachate and CSOs impact the Hackensack River along. The Hackensack River has experienced flooding, habitat destruction and fish community degradation, along with reduction of dissolved oxygen, excessive nutrients and accelerated eutrophication. These characteristics are attributed to the physical characteristics of the Hackensack River watershed and pollution from nonpoint sources.

F.7.3 Hydrodynamics

The Hackensack River begins in Rockland County, NY and has a length of approximately 50 miles and a drainage area of approximately 197 square miles. The Oradell Reservoir, completed in 1923, essentially divides the Hackensack into upper and lower regions. United Water currently diverts flow from the Oradell Reservoir for water supply to 750,000 residents of Bergen and Hudson Counties. The diversion of flow essentially cuts off the flow to the Hackensack River during dry-weather, which has altered the natural conditions of the river. The area of interest for this project begins at the Oradell Reservoir Dam and flows approximately 22 miles to the confluence of Newark Bay. The average flow in the Hackensack River is approximately 1.6 m^3/sec (56 cfs) and a maximum flow of approximately 158 m^3/sec (5,500 cfs) was measured in September 1999 during Hurricane Floyd. At Little Ferry the river is joined by Overpeck Creek. There is some indication, based on an analysis of salinity, that an additional 2.8 to 4.2 m^3/sec (100 to 150 cfs) additional freshwater flow joins the Hackensack River via groundwater along this length of the river. The Bergen County Municipal Utilities Authority's Little Ferry Water Pollution Control Facility adds approximately 4.2 m^3/s (80 MGD) of flow to the river during normal operations and contributes up to 13.1 m^3/s (250 MGD) during wet-weather.

In the Hackensack River, salt can penetrate about 15 miles from the river mouth due to relatively low freshwater inflows over the Oradell Dam. The lower section of the Hackensack River consists of vast area of tidal wetlands, known as the Meadowlands. USEPA's National Wetland Inventory identifies about 1,500 acres of the wetland area that are submerged under average tidal

Figure F-5: The Hackensack River

condition. Hydrodynamics in the Passaic River system are complicated by the presence of these large intertidal marshes on the Hackensack River. This is due to the fact that these marshes can provide significant water storage over a tidal cycle and during and after storm events, thereby altering the movement of water up the Hackensack River and to a lesser degree, the Passaic River.

F.7.4 Shoreline Characteristics

The Hackensack River is bordered by tidal wetlands, parking lots, and industrial and residential buildings. Historical wetland loss due to industrialization, land development has transformed the Hackensack Meadowlands District into a brackish tidal estuary. The Hackensack River experiences tidal fluctuations and seasonal wet weather events that flood the adjacent wetlands and tributaries.

F.7.5 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

The Hackensack River is listed on the 303 (d) list as being impaired for the following pollutants:

- Arsenic
- Benzo(a)pyrene (PAHs)
- Chlordane in Fish Tissue
- DDT and its metabolites in Fish Tissue
- Dieldrin
- Dioxin (including 2, 3, 7, 8-TCDD)
- Enterococcus
- Heptachlor epoxide
- Mercury in Fish Tissue
- Oxygen, Dissolved
- PCB in Fish Tissue
- pH
- Phosphorus (Total)
- Turbidity

F.7.6 Designated Uses and Water Quality Criteria from NJ Administrative Code

NJAC Section 7:9B Surface Water Quality Standards lists the Hackensack River as SE1 in the Overpeck Creek reach, SE2 in the Little Ferry reach, and SE3 in the Kearny Point reach. The classification SE1, SE2 and SE3 all refer to saline estuarine water bodies. Classifications along with designated uses, indicator bacteria and their criteria are shown in **Table F-6** below.

Table F-6: NJAC Regarding the Passaic River

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 mL)
SE1	Shellfishing; Primary Contact	Enterococci	35 GM, 104 SSM
SE2	Secondary Contact	Fecal Coliform	770 GM
SE3	Secondary Contact	Fecal Coliform	1500 GM

F.7.7 Designated Zone and Water Quality Regulations from the IEC

The IEC classifies the mouth of the Hackensack River as Class B-1. For more information regarding the IEC standards for Class B-1 water bodies, see Section B.2.4.

F.8 IDENTIFICATION OF SENSITIVE AREAS

F.8.1 Regulatory Requirements

Requirements of the USEPA's CSO Control Policy and Sensitive Areas Definition

The USEPA's CSO Control Policy (Federal Register 59 [April 19, 1994]: 18688-18698) "expects a permittee's long-term CSO control plan to give the highest priority to controlling overflows to sensitive areas" (Section II.C.3).

The CSO Control Policy states the six (6) criteria for defining an area as a "Sensitive Area" include:

1. Designated Outstanding National Resource Waters
2. National Marine Sanctuaries
3. Waters with threatened or endangered species and their habitat
4. Waters with primary contact recreation
5. Public drinking water intakes or their designated protected areas
6. Shellfish beds

The CSO Control Policy states that if Sensitive Areas are present and impacted, the LTCP should include provisions to:

- Prohibit new or significantly increased overflows
- Eliminate or relocate overflows wherever physically possible and economically achievable
- Treat overflows where necessary
- Where elimination or treatment is not achievable, reassess impacts each permit cycle

NJDES Permit Requirements

Sensitive Areas should be considered prior to the evaluation of CSO control alternatives. This allows a CSO community to identify and estimate costs for controls that could eliminate or relocate CSOs from Sensitive Areas where pollutant loadings pose a high environmental or public health risk and where control efforts should be focused. The cost of these controls can then be considered, along with the community's financial capability, to evaluate cost-effective controls for all of the receiving waters.

The NJPDES permits indicate that the permittee's LTCP shall give the highest priority to controlling overflows to sensitive areas. The NJPDES Permit further states that "Sensitive areas include designated Outstanding National Resource Waters, National Marine Sanctuaries, waters with threatened or endangered species and their habitat, waters used for primary contact recreation (including but not limited to bathing beaches), public drinking water intakes or their designated protection areas, and shellfish beds."

The NJPDES Permits indicate that if Sensitive Areas are present and impacted, the following requirements will apply:

- Prohibit new or significantly increased CSOs.
- Eliminate or relocate CSOs that discharge to sensitive areas wherever physically possible and economically achievable, except where elimination or relocation would provide less environmental protection than additional treatment.
- Where elimination or relocation is not physically possible and economically achievable, or would provide less environmental protection than additional treatment, the permittee shall provide the level of treatment for remaining CSOs deemed necessary to meet WQS for full protection of existing and designated uses.

F.8.2 Summary of Sensitive Areas

A comprehensive review of online databases, direct observations and correspondence with regulatory agencies and local environmental organizations was conducted to identify potential Sensitive Areas within the combined sewer system portion of the collection system and in the associated receiving waters.

Outstanding National Resource Waters (ONRW) are maintained and protected by Tier 3 of the USEPA's Anti-degradation Policy. Only waters of "exceptional ecological significance" qualify as ONRWs, as determined by States and Tribes. No Outstanding National Resource Waters were located within the project boundaries.

The Office of National Marine Sanctuaries (ONMS) is the trustee of all national marine sanctuaries which currently recognizes fourteen (14) national marine sanctuaries, none of which are located within PVSC's Study Area.

The resources from the US Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), New Jersey Heritage Program (NJHP), and New Jersey DEP Division of Fish and Wildlife (NJDFW) were utilized to identify several Endangered or Threatened species which potentially could live in the project area. All species listed by United States Fish and Wildlife Service are included in NJDEP's lists. NOAA maps show potential areas that may have endangered or threatened species during parts of the year. However, both NJHP and NJDEP's correspondence indicate there are no critical habitats for these species found in the waters of the Study Area. Since CSOs impact receiving water bodies, Endangered or Threatened species that have been identified but do not require the receiving water bodies to live, propagate, and eat in an area cannot be considered to be in their critical habitat. It is unclear if the identified areas are critical for the species' conservation when other areas are providing similar if not additional needs. Atlantic and Shortnose sturgeon may share their critical habitat in CSO discharge areas, but poor water quality is not inhibiting Atlantic sturgeon recovery, and Shortnose sturgeon have surpassed the recovery criteria in the adult population for the past few decades. The current water quality and habitat protections are viewed as adequate to maintain a healthy sturgeon population. The impact of human enteric pathogens on sturgeon should not have any negative effects on sturgeon at any life stage of the fish both now and in the future, and only commercial bycatch and prior environmental degradation is viewed as a stressor threatening sturgeon recovery.

There are thirteen locations where endangered or threatened species have been identified near permitted CSOs, but no certainty of a critical habitat existing at these locations. Primary contact was not observed or expected in the Passaic River throughout Paterson and is therefore not considered a Sensitive Area. Beaches on the Southeastern boundary of the City of Perth Amboy are not currently designated by the city for recreational bathing use, and signs are installed at this location in order to advise the public against swimming or entering the water. While monitoring this area is a priority, it is not considered a Sensitive Area.

There are no Sensitive Areas as a result of active drinking water intakes within the study area.

There are no commercial shellfish harvesters that operate within the service area. For details of the Sensitive Area Study see the Identification of Sensitive Areas Report dated June 2018 submitted to the NJDEP on behalf of the participating permittees by the PVSC.

SECTION G - COLLECTION OF WATER QUALITY DATA

G.1 BACKGROUND

The NJDEP, PVSC and the leadership of the CSO permittees have agreed that a cooperative or regional approach to the development of a single CSO LTCP is desirable. PVSC has agreed to develop a sewer system characterization work plan on their behalf from its QAPPs for its hydraulically connected CSO Permittees. Several coordination meetings have been held with representatives of the CSO permittees tributary to PVSC's conveyance and treatment facilities as well as other participating CSO permittees. PVSC has agreed to lead the Combined Sewer System Characterization and Landside Modeling Tasks, as well as the Baseline Compliance Monitoring Program, on behalf of the participating permittees.

In accordance with consultation with NJDEP, multiple Sewer System Characterization Work plans QAPPs were developed to cover different aspects of the LTCP work activities for the eight combined sewer municipalities. The QAPPs for the Baseline Compliance Monitoring Program (BCMP) and Receiving Water Quality Modeling were submitted separately from the Sewer System Characterization Work Plan QAPP. The BCMP was developed to serve all of the North Jersey CSO permittees. This System Characterization Report has been developed to include PVSC and seven of the CS municipalities per agreement with each municipality. Jersey City MUA will submit their own System Characterization Report.

The Sewer System Characterization Work Plan was developed to quantify and qualify wastewater and pathogen concentration variations at key CSO and stormwater drainage basins. The Sewer System Sampling Program is outlined in Section G.3 and results are provided in Section G.4 below.

The Baseline Compliance Monitoring Program (BCMP) is modeled in part on the program performed by the New Jersey Harbor Dischargers Group. NJHDG is a similarly allied collaborative undertaking that includes nine (9) sewerage agencies representing eleven (11) wastewater treatment plants in northeastern New Jersey that discharge into the New Jersey portion of the NY/NJ Harbor Estuary. The purpose of NJHDG's long-term water quality monitoring program is to develop ambient water quality data for the Hackensack River, Passaic River, Rahway River, Elizabeth River, Raritan River, Raritan Bay, Newark Bay, and the New Jersey portions of the Hudson River, Upper New York Harbor, and the Arthur Kill, allowing long-term evaluation of water quality in these areas by providing baseline and annual information on water quality in these waterbodies as it relates to current water quality standards. This evaluation identifies changes in water quality over time under varying seasonal conditions, providing a basis for documenting pollution sources and water quality improvements resulting from the implementation of pollution control programs. The Receiving Water Quality Monitoring Program focuses on the CSO receiving waters and is outlined in Section G.6 and a summary of the results are provided in Section G.7 below. The complete Water Quality BCMP results and analysis are provided under a separate report, Baseline Compliance Monitoring Program Report.

G.2 REGULATORY REQUIREMENTS

G.2.1 NJPDES Permit Requirements

PVSC holds NJPDES Permit No. NJ0021016. For more information regarding NJPDES Permit Regulations, see Section B.2.1.

G.2.2 USEPA's CSO Control Policy and Guidance Documents

USEPA's CSO Control Policy (Policy) provides guidance to municipal permittees with CSOs, to the state agencies and to state and interstate water quality standards authorities. The Policy establishes a framework for the coordination, planning, selection and implementation of CSO controls required for permittee compliance with the Clean Water Act. For more information regarding the USEPA's CSO Control Policy, see Section B.2.2.

Requirements for the Monitoring and Modeling Plan are established in the USEPA's "CSO Guidance for Monitoring and Modeling". For more information on other USEPA CSO Guidelines, see Section B.2.3.

G.2.3 Interstate Environmental Commission Requirements

The Interstate Environmental Commission (IEC) is an air and water pollution control agency that serves the Interstate Environmental District within the states of New York, New Jersey, and Connecticut. The Commission's goal is to protect the environment and assure compliance with and enforcement of its Water Quality Regulations. For more information on IEC, see Section B.2.4.

G.3 OVERVIEW OF SEWER SYSTEM QUALITY MONITORING PROGRAM

G.3.1 Historic CSO Discharge Monitoring

The following historical report provided background information on the combined sewer systems tributary to each regulator as well as the analysis of historical overflow volumes and pollutants contained in the CSO discharges.

CSO Monitoring Report (December 1998): This effort was intended to quantify and qualify dry weather and wet weather wastewater flow and pollutant concentration variations at key CSO drainage basins so that this information can be used to calibrate and verify hydrologic and hydraulic models of the combined sewer systems for the combined communities within the PVSC service area tributary to PVSC's Interceptor Sewer and Newark's Southside Interceptor.

G.3.2 Sewer System Quality Monitoring Objectives

The purpose of the monitoring program was to quantify and qualify dry weather and wet weather wastewater flow and pathogen concentration variations at key CSO and stormwater drainage basins to calibrate and verify hydrologic and hydraulic models (InfoWorks) of the CSSs within the PVSC service region. This data was used to update the mathematical tool (sewer system model) that will be used to assess storage and maximum hydraulic conveyance capacity in the PVSC interceptor system, pathogen concentrations and loading distributions during storm events and among CSO discharge points, calculate pathogen loads from CSOs and stormwater to the receiving water, and for the development and evaluation of long term control alternatives and/or modifications to the water quality standards (WQS) during wet weather events.

G.3.3 Sewer System Quality Sampling Locations

The original Quality Assurance Project Plan (QAPP) targeted 18 CSO and 8 stormwater locations, distributed throughout the PVSC region by municipality and land use. See **Figure G-1** for an overview of the sampling locations. The goal of the sampling protocol was to obtain three wet-weather events of sufficient depth, intensity, and duration for valid model calibration at each targeted location. This was the case for all eight stormwater locations; however, only one of the 18 CSO locations was successfully sampled three times, and four of the targeted CSO locations were not sampled at all due to access or other logistical issues.

CSO locations were sampled prior to overflow, then at the following intervals: 0.5 hour, 1 hour, 2 hours, 4 hours, and 8 hours. During the execution of the sampling, the last of these samples was often truncated because the event stopped, so crews routinely collected the last sample any time after 6 hours from start of the event or overflow. Stormwater locations were sampled four times per event, generally on an hourly basis but adjustments were made as events progressed to capture as much of a precipitation event as possible.

G.3.4 Analytical Parameters

Water quality sampling at each location included grab samples and analysis for fecal coliform and enterococcus. Grab samples for analysis of E. coli were also collected at monitoring sites where the outfall discharges to a fresh water receiving waterbody. Laboratory Methods utilized are shown in **Table G-1**.

Table G-1: Lab Methods

Parameter	Laboratory Method	Preservation	Holding Time	Reporting Limit
Fecal Coliform	EPA Micro Manual p. 124 (1978), Single Step Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 CFU/100 mL
Enterococcus	EPA 1600 (Dec 2009), Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 PE/100 mL
E. coli	EPA 1603 (Dec 2009), Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 CFU/100 mL

CFU: colony forming units; PE: presumptive enterococci.

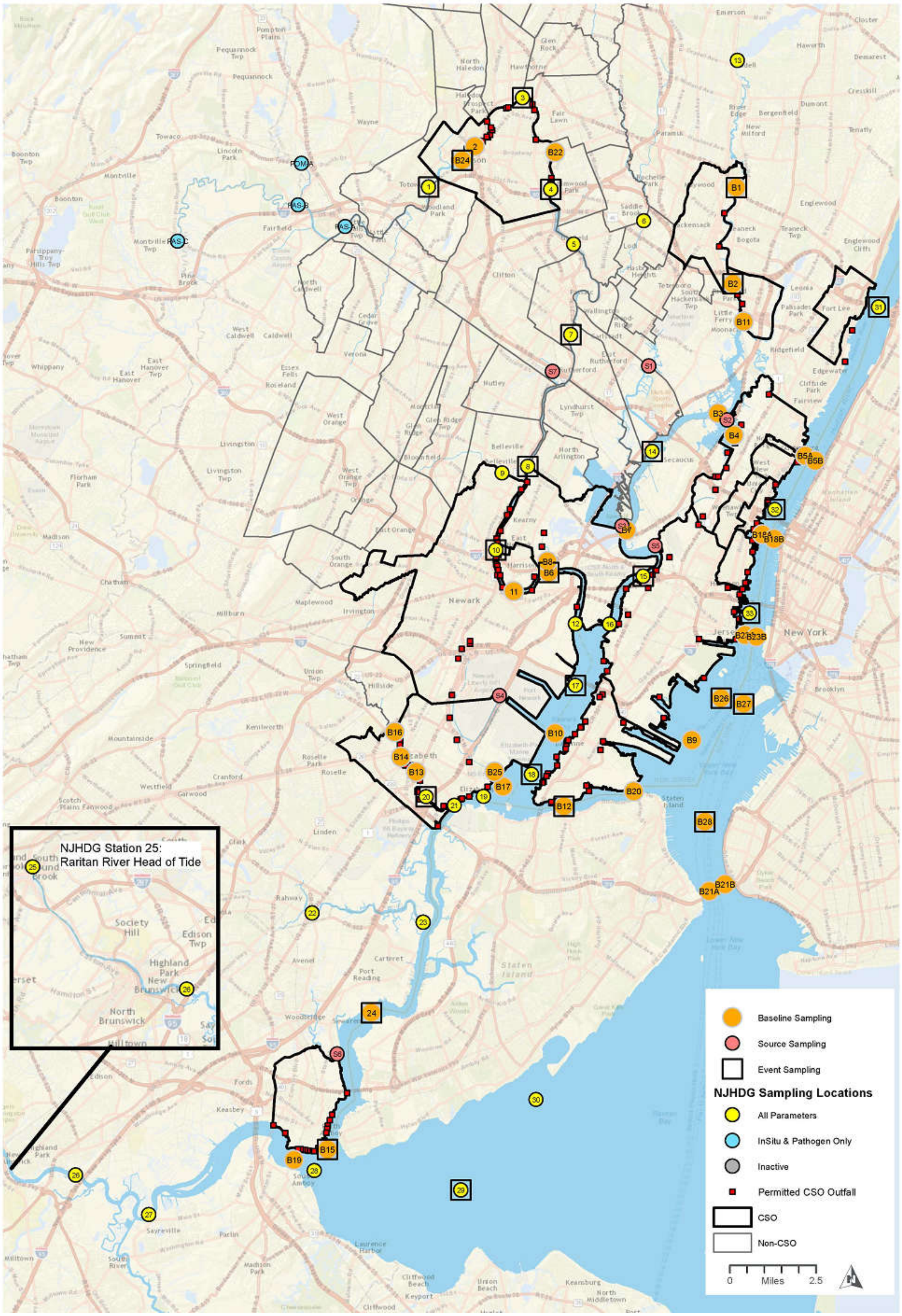


Figure G-1: Overview of Sampling Station Locations

G.3.5 Sampling Schedule and Dates

Water quality sampling was performed. A summary of the CSO sampling dates with corresponding locations and sample identification numbers are shown in **Table G-2** and **Table G-3** below.

Table G-2: CSO Sampling Dates

Date	Locations	CSO Sample Identification
8/21/2016	1	PAT-06A
11/29/2016	5	HAR-06A, HAR-07A, KEA-07A, NWK-25A, NWK-45A
4/4/2017	4	HAR-06A, HAR-07A, KEA-07A, NWK-91A
4/6/2017	4	NWK-14A, NWK-45A, PAT-06A, PAT-29A
6/19/2017	4	BAY-08A, BAY-10A, PAT-25A, PAT-27A
7/13/2017	3	GUT-01A, PAT-25A, PAT-27A
7/22/2017	2	BAY-08A, BAY-10A
10/24/2017	4	NWK-14A, NWK-25A, NWK-45A, NWK-91A
Total	**8**	**Unique CSO Locations**
Total	**27**	**CSO Location-Events**

Table G-3: Stormwater Sampling Dates

Date	Locations	Stormwater Sample Identification
7/29/2016	2	OAK-LR4, PAT-LR1
9/19/2016	2	NWK-CI2, PAT-LR1
9/30/2016	2	NWK-CI2, OAK-LR4
10/21/2016	1	NWK-HR1
11/15/2016	4	NWK-CI2, NWK-HR1, OAK-LR4, PAT-LR1
12/6/2016	1	NWK-HR1
1/17/2017	2	NWK-HR2, NWK-LR2
5/5/2017	4	HAW-LR3, NWK-HR2, NWK-LR2, PAT-CI1
5/22/2017	2	NWK-HR2, NWK-LR2
5/25/2017	2	HAW-LR3, PAT-CI1
7/6/2017	2	HAW-LR3, PAT-CI1
Total	**11**	**Unique Stormwater Locations**
Total	**24**	**Stormwater Location-Events**

G.3.6 System Characterization and Landside Modeling QAPP Goals

The project goals and objectives for the System Characterization and Modeling Program presented herein included:

- Supplement and update, as appropriate, the site specific dry and wet weather data to be used to recalibrate and verify the InfoWorks collections system model of those collections systems tributary to the PVSC WRRF.

- Define the CSSs' hydraulic response to rainfall.
- Supplement the existing dry weather water quality and quantity data to be used in the representation of each CSO drainage basin.
- Determine the CSO flows and pathogen concentrations/loadings being discharged to the receiving streams as a result of varied rainfall events.
- Supplement the stormwater quality data for various land use applications.

G.4 SEWER SYSTEM QUALITY RESULTS

Graphs of data collected by HDR during April 2016 through March 2017 are presented in **APPENDIX A**. Stormwater data were collected in areas that were meant to represent low-density residential, high-density residential and industrial/commercial land-use areas. An analysis of the data indicated that the measured stormwater concentrations were similar in the various land-use areas, so the data were combined to represent stormwater in general. **Table G-4** presents the maximum likelihood estimation (MLE) of the stormwater pathogen data. An MLE can be used estimate a mean of a log-normally distributed dataset. The enterococci concentrations are high when compared to the fecal coliform concentrations, but will form the starting point for estimating the stormwater concentrations in the modeling analysis.

Table G-4: MLE of Stormwater Pathogen Data

	Fecal Coliform (cfu/100mL)	Enterococci (cfu/100mL)	E. coli (cfu/100mL)
MLE	41,103	110,016	38,253

The CSO data will be used to verify the CSO concentrations calculated by using a combination of sewer system model output and estimated sanitary and stormwater pathogen concentrations. This "Mass Balance Approach" will be used to estimate pathogen loading from CSOs in the receiving water model.

G.4.1 Plant Influent Sampling and Results

Fecal coliform, enterococci, and E. coli concentrations were measure in PVSC plant influent for the period of July 11, 2016 through February 8, 2018. These concentrations will be used to assign the concentrations for the sanitary fraction of the CSO flow that will be used to calculate CSO pathogen concentrations for use in the receiving water quality model that will be used to support the LTCP CSO alternatives assessment. **Table G-5** provides a summary of the concentrations collected. Fecal coliform had the highest concentrations, followed by E. coli, and then enterococci. Fecal coliform and E. coli showed a seasonal pattern with higher concentrations in the warmer months and lower concentrations in the cooler months. A seasonal trend was not evident in the enterococci concentration data.

Table G-5: Pathogen Concentration Summary

Statistic	Fecal Coliform (cfu/100mL)	Enterococci (cfu/100mL)	E. coli (cfu/100mL)
Average	3,722,595	682,661	2,616,057
MLE	3,804,207	700,260	2,716,496
Geometric Mean	2,771,484	597,075	2,127,581
Minimum	160,000	4,000*	100,000
Maximum	47,000,000	6,200,000	7,200,00

* A value of < 2 cfu/100mL was recorded but not considered valid

G.5 OVERVIEW OF HISTORICAL RECEIVING WATER QUALITY MONITORING

G.5.1 Historic Water Quality Sampling

The New Jersey Harbor Dischargers Group (NJHDG) is an allied collaborative undertaking that includes nine (9) sewerage agencies representing 11 wastewater treatment plants in northeastern New Jersey that discharge into the New Jersey portion of the NY/NJ Harbor Estuary. PVSC, BCUA, JMEUC, MCUA, NBMUA, NHSA are overlapping members of NJHDG and the NJ CSO Group. These agencies collaborate, jointly fund, and perform various water quality studies in the region.

In 2003, the NJHDG initiated a Long-Term Ambient Water Quality Monitoring Program for the NJ portion of the NY/NJ Harbor Estuary. PVSC had previously initiated a long-term ambient water quality monitoring program of the Passaic River, Hackensack River, and Newark Bay in 2000, and has taken the lead for the NJHDG monitoring program. The NJHDG monitoring program is modeled after the successful New York City Department of Environmental Protection (NYCDEP) Harbor Survey. The main objective of the NJHDG program is to develop a comprehensive database on the existing water quality of the NY/NJ Harbor by routinely and extensively monitoring the waters of the Hackensack River, Passaic River, Rahway River, Elizabeth River, Raritan River, Raritan Bay, Newark Bay, and the New Jersey portions of the Hudson River, Upper New York Harbor, and the Arthur Kill. The data collected allows long-term evaluation of water quality in these areas by providing baseline and annual information on water quality in these waterbodies as it relates to current water quality standards. This evaluation identifies changes in water quality over time under varying seasonal conditions, providing a basis for documenting pollution sources and water quality improvements resulting from the implementation of pollution control programs.

Thirty-four locations throughout the region are monitored for 18 conventional chemical water quality parameters including: temperature, pH, dissolved oxygen (DO), salinity, Secchi depth, total suspended solids (TSS), 5-day carbonaceous biochemical oxygen demand (CBOD-5), total Kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), ammonia-nitrogen (NH_3-N), total phosphorus (TP), orthophosphate (OP), dissolved organic carbon (DOC), chlorophyll-a (Chlor-a), fecal coliform bacteria and Enterococcus bacteria. **Figure G-1** presents the monitoring station locations. Monitoring is performed at each station biweekly during May

and June, weekly from July through September and monthly from October through April. All resources for the monitoring program, including sampling personnel and laboratory analyses, are provided by the NJHDG member agencies.
The NJHDG program has effectively served to eliminate the data gap for NJ waters of the NY/NJ Harbor Estuary system by monitoring waterbodies that are not currently monitored by the New Jersey Department of Environmental Protection (NJDEP) Surface Water Quality

Monitoring Network, United States Geological Survey (USGS) Surface Water Quality Gages, or the United States Environmental Protection Agency (USEPA) New York Bight Water Quality Monitoring Program.

This program formed the basis of the LTCP sampling program as described in Section G.4.

G.6 OVERVIEW OF THE RECEIVING WATER QUALITY MONITORING PROGRAM

G.6.1 Receiving Water Quality Monitoring Objectives and Baseline Compliance Monitoring

The Baseline Compliance Monitoring Program has the following objectives:

- Fulfilling the CSO Permit requirement under paragraph D.3.c and under paragraph G.9 for ambient monitoring.
- Generating sufficient data for establishing existing ambient water quality conditions for pathogens to foster appropriate regulatory decisions based on current water quality measurements.
- Generating sufficient relevant data under wet and dry conditions to be used to update, calibrate and validate a pathogen water quality model of the receiving water bodies.
- Supporting the goals of the other components of the LTCP (System Characterization and Receiving Water Quality Modeling).

The Baseline Compliance Monitoring Program includes three parallel data collection efforts to achieve these objectives:

1. Baseline Sampling, which may supplement data from the ongoing NJHDG annual program;
2. Source Sampling, which will target the major influent streams within the study area to establish non-CSO loadings, and will coincide with the NJHDG and Baseline Sampling; and
3. Event Sampling, which is timed to coincide with rainfall to capture three discrete wet-weather events over the course of the year on each segment of the NY-NJ Harbor complex impacted by CSOs.

G.6.2 Receiving Water Quality Sampling Locations

Sampling stations were located to supplement the existing NJHDG monitoring program to provide additional spatial coverage and ensure that each permittee had at least one monitoring station in its local waterbody. A total of 35 additional baseline monitoring stations were added to the existing 34 NJHDG stations. Twenty-five of those 69 stations were chosen for event sampling. An additional seven source sampling stations were added to identify other sources of bacteria to the system. All of the monitoring stations are presented in **Figure G-1**. Shallow stations were sampled at mid-depth and deeper stations were sampled at near surface and mid-depth.

G.6.3 Analytical Parameters

The focus of the LTCP is pathogens. Accordingly, the sampling program was created to measure pathogens and the factors that can affect their concentrations.

Field Testing

The following parameters were directly measured in the field:

- Dissolved Oxygen (DO)
- Temperature
- pH
- Salinity
- Secchi depth (where applicable)
- Turbidity

Methods, reporting limits, method detection limits and holding times are presented in **Table G-6**.

Table G-6: Field Methods

Parameter	Method	Reporting Limit (RL)	Method Detection Limit (MDL)	Holding Time
Temperature (°Celsius)	SM 2550 B	0.1 °C	0 °C	Analyze Immediately
Salinity (parts per thousand)	SM 2520 B	0.1 ppt	0 ppt	Analyze Immediately
Dissolved Oxygen (milligrams per liter)	SM 4500-O C SM 4500-O G	0.1 mg/L	0 mg/L	Analyze Immediately
pH	SM 4500-H B EPA 150.2	0.1	0	Analyze Immediately
Light Penetration (feet)	Secchi Depth	0.1 ft	0.1 ft	Analyze Immediately
Turbidity (Nephelometric Turbidity Units)	SM 2130 B	0 NTU	0 NTU	Analyze Immediately

Laboratory Testing

The following parameters were analyzed at Eurofins QC, Inc.:

- Fecal Coliform (all locations)
- Enterococcus (all locations)
- E. coli (freshwater locations only; Elizabeth River & Upper Passaic River)

Methods, reporting limits, preservation and holding times are presented in **Table G-7**.

Table G-7: Lab Methods

Parameter	Laboratory Method	Preservation	Holding Time	Reporting Limit
Fecal Coliform	EPA Micro Manual p. 124 (1978), Single Step Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 CFU/100 mL
Enterococcus	EPA 1600 (Dec 2009), Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 PE/100 mL
E. coli	EPA 1603 (Dec 2009), Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 CFU/100 mL

CFU: colony forming units; PE: presumptive enterococci.

G.6.4 Sampling Schedule and Dates

The Baseline Sampling is modeled after the approved routine sampling program of the NJHDG. However, the proposed Baseline Sampling targeted additional locations to supplement NJHDG data and enhance overall spatial coverage. The Baseline sampling occurred over a period of 12-months from April 2016 through March 2017. The sampling frequency matched the NJHDG program, varying with time of year as follows:

- Spring (May-Jun): Biweekly (4 dates)
- Summer (Jul-Sep): Weekly (12 dates)
- Winter (Oct-Apr): Monthly (7 dates)

The Baseline Sampling and the NJHDG program provided a seasonally-based characterization of existing water quality. All sampling dates for the Baseline Sampling were predetermined at the initiation of the program. For the purposes of the Baseline Compliance Monitoring Program, a sampling date was considered to be wet weather if 0.2 inches of rain or more fell within 24 hours prior to sample collection. Source Sampling coincided with Baseline Sampling.

G.6.5 QAPP Overview

The Baseline Compliance Monitoring Program QAPP was finalized on February 19, 2016. The QAPP included four standard sections: Project Management, Data Generation and Acquisition, Assessment and Oversight, and Data Validation and Usability as outlined in Guidance for Quality Assurance Project Plans, EPA QA/G-5 (EPA 2002). The plan outlined the necessary steps to achieve a successful monitoring program.

Table G-8 presents the quality targets outlined in the QAPP.

Table G-8: Data Quality Criteria and Performance Measurement for Field Collection

Data Quality Indicator	Performance Criterion	Assessment Activity
Completeness	Valid data from 90% of collected samples	Percentage of valid measurements
Precision	RPD[1] < 30% for duplicates	1 field duplicate/crew-day
Representativeness	Blanks <u><</u>MDL[2]	1 field blank/crew-day 1 equipment blank/crew-day

[1]Relative Percent Difference on a log basis; non-representative when (a) both the original and duplicate results are not detected or are less than 5x the reporting limit or (b) either result is estimated, rejected, or suspected of contamination. [2]Method Detection Limit, calculated where applicable.

The sampling program achieved its targeted performance criteria. The data collected in this program should provide an adequate characterization of the variable water quality of receiving waters in the project area.

G.7 RECEIVING WATER QUALITY RESULTS

The field work completed consisted of Baseline Sampling, Source Sampling and Event Sampling as outlined in Section G.4. Field work for these three elements was completed on April 28, 2017; the last of the laboratory results were provided June 10, 2017. A total of 23 baseline and source sampling events were completed. The goal of the event sampling was to capture three significant wet weather events (precipitation >0.5 inches in 24 hours) at each targeted station, which was completed across four sampling events (one set of samples was collected across two precipitation events). All samples collected were analyzed for fecal coliform and enterococcus; freshwater samples were also analyzed for E. coli.

The data collected under the Baseline Compliance Monitoring Program appears to be sufficient for the intended goal of calibrating the water quality model to be used for PVSC and NJCSO communities' LTCPs.

The BCMP was not designed to provide an adequate data volume for assessing attainment of water quality standards, which would have required five samples per month at each sampling location to compute monthly geometric means. However, a review of the data collected can indicate the likelihood of attainment in a particular area:

- The lower regions of the Passaic and Hackensack Rivers appear likely to violate water quality criteria, but attainment appears to improve closer to Newark Bay.
- The larger waterbodies (Newark Bay, Hudson River, Arthur Kill, Kill Van Kull) appear to meet existing water quality criteria. Newark Bay and the Kills are primarily SE3 waterbodies, and Raritan Bay is subject to more stringent shellfishing water quality standards.

- Several smaller riverine waterbodies appear unlikely to meet attainment. This includes the Rahway River, Saddle River, Second River, and Elizabeth River. The Raritan River may also have attainment issues.
- Many rivers without CSOs have high bacteria loads. Data collected at source sampling locations indicate non-attainment of waters entering the Passaic and Hackensack Rivers, contributing pollutant loads into the study area from areas that do not have CSOs.

The companion document Baseline Compliance Monitoring Program Data Summary provides a more comprehensive summary of the water quality results.

SECTION H - TYPICAL HYDROLOGIC PERIOD

H.1 INTRODUCTION

H.1.1 Typical Year for CSO LTCP Development

Precipitation generates urban storm water and combined sewer overflows (CSOs). These will contribute bacteria and pollutants to the New York-New Jersey Harbor and its surrounding major tributaries. The effect of these contributors on the receiving streams mainly depends on the magnitude and duration of rainfall events and on the prevailing ambient river conditions controlling dilution and transport of the pollutants. This variability and complexity poses a significant challenge for assessing the performance of wet weather and CSO control alternatives.

In accordance with the Combined Sewer Overflows - CSO Control Policy from the U.S. Environmental Protection Agency, Office of Water, Washington, DC, EPA 830-B-94-001, April 1994 and the NJDEP Master General Permit issued January 1995, the CSO control alternatives should be assessed on a "system-wide, annual average basis". This is accomplished by continuous simulation using a typical hydrologic period for the combined sewer system (CSS) and receiving water quality modeling applications. The CSO Policy supports continuous simulation modeling, i.e., using long-term precipitation records rather than records for individual storms. Long-term continuous precipitation records enable simulations to be based on a sequence of storms so that the additive effect of storms occurring close together can be examined. They also enable storms with a range of characteristics to be included.

The typical year is intended to contain the closest to average year for the years with available data. Average year conditions are defined as the arithmetic average of the predictions for the selected period.

H.1.2 Annual Precipitation Trend 1948-2015

Average U.S. precipitation has increased since 1900, but there are regional differences, with some areas having larger increases, and others, decreases. Local climate change should be considered when selecting appropriate data records for the typical period analysis.

Daily precipitation data from Newark Liberty International Airport were obtained from the National Oceanic and Atmospheric Administration (NOAA) from 1948 through 2015 to evaluate precipitation trend.

Figure H-1 shows annual precipitation depth from 1948 to 2015. An average straight trend line using sum of least squares is also shown in the figure for characterizing long-term precipitation pattern. During 1948 through 2015, annual precipitation depth ranges from 26.9 to 69.91 inches, with the driest year in 1963 and the wettest year in 2011. The figure splits to show the trend line change from 1948 to 1970 contrasted to 1970 to 2015. From 1948 to 1970 shows a declining pattern with an approximate change of 0.337 inch per year. From 1970 to 2015 shows an inclining pattern with an approximate change of 0.032 inch per year. The latter trend line is more relevant to present day. Therefore it is determined that the typical period for the LTCP to be selected based on statistical analysis of precipitation records in recent 46 years (i.e., 1970-2015).

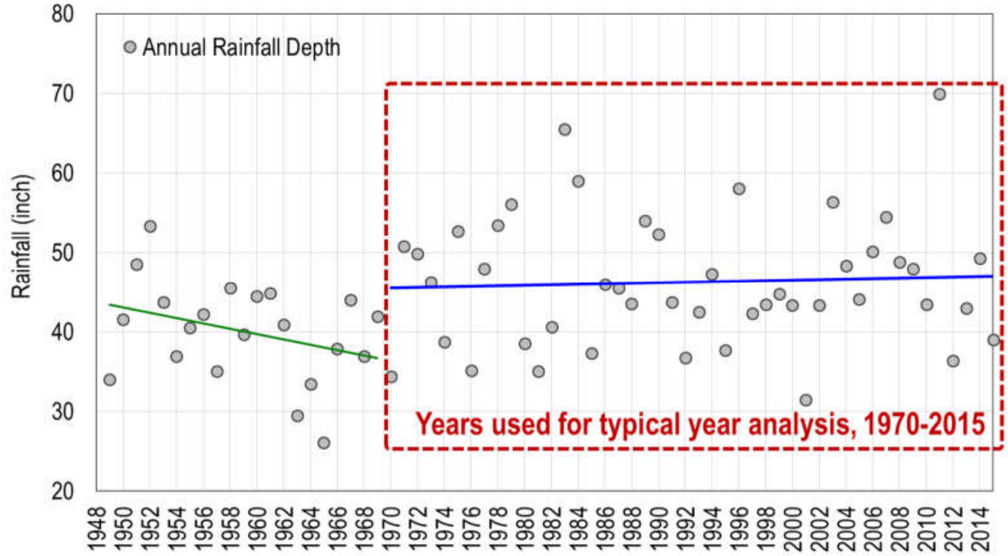


Figure H-1: Historical Annual Precipitation at Newark Liberty International Airport

H.1.3 Methodology of Typical Year Selection

The typical hydrologic year is selected to provide representative and unbiased approximations of expected conditions in terms of both averages and historical variability. Representativeness is assessed using objective criteria for each of the ambient factors. As indicated in the previous section, the selection of the typical hydrologic period is based on the historical records in the past 46 years from 1970 through 2015. The following datasets are used for the analysis of the typical hydrologic period:

- Hourly precipitation data for the National Climate Data Center gauge at Newark Liberty International Airport for 1970 - 2015 is used for analyzing individual rainfall event and event characteristics.
- Daily precipitation data for the National Climate Data Center gauge at Newark Liberty International Airport for 1970 - 2015 is used for analyzing annual and seasonal precipitation amounts.

Criteria used in this typical year analysis were developed based on requirements listed in the presumption approach and the demonstration approach, and potential operational and maintenance considerations for CSO control facilities (EPA's CSO Control Policy, 1994).

Key criteria parameters used in the evaluation are listed in **Table H-1**. Each parameter is given a weighting factor to describe the individual importance on the averageness of the analyzed time period.

Table H-1: Typical Hydrologic Year Ranking Parameters

Criteria Parameter	Weighing Factor	Description / Importance
Annual rainfall depth	30%	Impacting annual overflow volume and storage volume
# of events with rainfall depth ≥ 0.2 in	10%	Rainfall depth to trigger overflow in existing system
# of events with rainfall depth ≥ 0.1 in	5%	Rainfall depth to trigger surface runoff
5th largest storm volume	5%	Determining max storage capacity or WRRF capacity
Rainfall volume for 85% captured	5%	Determining max storage capacity or WRRF capacity
# of back-to-back rainfall events	10%	Determining antecedent conditions and potential storage facility operation
Maximum peak intensities of the 5th largest storm and less	5%	Determining the sizing of conveyance pipes, diversions, regulators, pumps, etc.
# of storms with return frequency ≥ 1-year	5%	Extremely large storms to be avoided
Average Rainfall Duration	15%	Determining storage capacity
Average Rainfall Intensity	10%	Determining storage capacity including pipes, regulators, diversions, etc.

H.2 TYPICAL YEAR SELECTION

H.2.1 Annual Rainfall Statistics

The 46-year hourly precipitation data (1970 - 2015) from the Newark Liberty International Airport was analyzed to evaluate all individual rainfall events in the period. An inter-event time (IET) of 6 hours (i.e. minimum dry time of six hours between rainfall events) was used to differentiate between individual rainfall events. All rainfall events for the data period were analyzed for duration, inter-event time, total rainfall amount, as well as maximum rainfall intensities.

A total of 4,812 rainfall events were counted for the period of 1970 – 2015 (3022 events with a total depth ≥ 0.1 inch). Events with a total precipitation depth equal to or greater than 0.1 inch are used for further analysis. **Table H-2** summarizes rainfall events on an annual basis for annual rainfall depth, number of events above 0.2 inch, number of events above 0.1 inch, the 5th largest storm volume, rainfall volume for 85% captured, number of back-to-back rainfall events, maximum peak intensity of 5th largest and smaller events, number of events with return frequency of one-year and above, average rainfall duration, and average rainfall intensity. The average of the 46 years is shown at the end of the table for each criteria parameter.

Table H-2: Annual Rainfall Statistics 1970-2015

Year	Annual Rainfall (in)	# of Events > =0.2" Rainfall Depth	# of Events > =0.1" Rainfall Depth	5th Largest Storm (in)	Rainfall Volume for 85% Captured (in)	# of back-to-back events	Maximum Peak Intensity of 5th Largest & Smaller	# of Storms with Return Freq > 1-yr	Average Rainfall Duration (hr)	Average Rainfall Intensity (in/hr)
1970	34.39	50	64	1.07	0.77	17	0.98	0	9.36	0.080
1971	50.77	49	64	1.67	3.02	14	0.99	3	10.33	0.092
1972	49.86	57	82	1.78	1.35	14	0.62	4	11.00	0.060
1973	46.29	50	61	2.15	1.27	7	0.72	2	11.77	0.082
1974	38.76	54	74	1.2	0.93	11	0.88	1	9.16	0.076
1975	52.65	59	78	1.72	1.57	18	1.01	4	11.19	0.078
1976	35.19	50	66	1.3	0.94	11	0.91	2	9.14	0.082
1977	47.97	49	73	2.04	2.05	9	1.00	1	10.47	0.071
1978	53.41	51	72	2.42	1.54	13	1.28	5	11.85	0.073
1979	56.1	59	76	2.17	1.55	17	0.87	3	11.45	0.075
1980	38.51	37	48	1.85	1.32	4	0.71	2	11.15	0.079
1981	35.04	47	63	1.45	0.94	12	0.92	1	9.03	0.068
1982	40.58	44	55	1.54	1.15	8	0.75	1	11.20	0.068
1983	65.5	58	65	2.49	1.39	9	0.93	4	13.22	0.090
1984	59.01	51	71	1.98	1.63	9	0.94	7	10.90	0.087
1985	37.29	40	58	1.42	1.21	12	0.84	2	11.29	0.069
1986	45.95	52	67	1.77	1.43	13	0.76	2	11.03	0.072
1987	45.53	54	64	1.61	1.07	12	0.97	0	11.39	0.079
1988	43.51	55	59	1.66	1.12	10	0.80	2	10.81	0.078
1989	53.99	61	79	1.95	1.23	15	0.69	2	10.14	0.093
1990	52.3	62	79	1.88	1.08	11	1.04	2	9.78	0.096
1991	43.76	54	64	1.95	1.33	5	0.88	2	11.03	0.084
1992	36.74	46	65	1.31	1.22	9	0.80	2	11.09	0.058
1993	42.51	50	60	1.65	1.07	10	0.80	1	12.60	0.074
1994	47.32	57	72	1.76	1.16	12	0.96	0	11.18	0.077
1995	37.67	43	58	1.35	1.05	7	0.60	1	10.05	0.073
1996	58.07	63	76	2	1.30	10	1.09	3	10.09	0.086
1997	42.35	45	60	1.35	1.21	7	0.71	2	10.75	0.066
1998	43.47	43	56	1.89	1.42	10	1.23	2	11.59	0.089
1999	44.75	52	60	1.43	1.82	11	0.65	3	11.92	0.076
2000	43.35	49	63	1.43	1.02	10	0.50	2	10.24	0.081
2001	31.44	40	55	1.41	0.95	8	0.69	0	10.40	0.058
2002	43.37	49	54	1.67	1.14	5	1.03	1	12.24	0.107
2003	56.33	64	76	1.89	1.16	18	0.86	2	11.41	0.081

Year	Annual Rainfall (in)	# of Events > =0.2" Rainfall Depth	# of Events > =0.1" Rainfall Depth	5th Largest Storm (in)	Rainfall Volume for 85% Captured (in)	# of back-to-back events	Maximum Peak Intensity of 5th Largest & Smaller	# of Storms with Return Freq > 1-yr	Average Rainfall Duration (hr)	Average Rainfall Intensity (in/hr)
2004	48.37	54	73	1.63	1.18	12	0.99	3	10.33	0.084
2005	44.14	44	57	1.4	2.16	3	0.80	2	12.75	0.061
2006	50.16	52	65	2.01	1.44	12	1.17	3	11.26	0.078
2007	54.49	52	67	2.36	1.88	4	1.46	6	9.72	0.095
2008	48.83	49	69	1.84	1.34	11	0.77	3	10.04	0.094
2009	47.93	54	74	1.87	1.13	13	0.80	1	10.91	0.074
2010	43.47	44	52	1.6	1.51	10	0.93	2	12.08	0.103
2011	69.91	59	76	2.4	2.76	17	0.89	4	10.22	0.106
2012	36.35	51	68	1.47	0.94	11	1.01	1	8.81	0.095
2013	42.94	49	61	1.43	1.06	9	1.10	1	10.41	0.083
2014	49.33	60	69	1.56	1.24	10	1.26	2	10.99	0.083
2015	38.98	42	54	1.46	0.95	5	0.99	1	11.43	0.089
Average (1970-2015)	**46.3**	**51.2**	**65.7**	**1.72**	**1.35**	**10.54**	**0.90**	**2.2**	**10.9**	**0.081**

H.2.2 Ranking Analysis

With the weighting factors listed in **Table H-1**, a deviation score was developed for each individual period. The steps to perform the ranking analysis is discussed in detail in the *Typical Hydrologic Year Report* prepared for Passaic Valley Sewerage Commission (PVSC). The 1-year periods were then ranked based on the deviation score. The lower deviation score (**Figure H-2** Y-axis), the higher the rank for the hydrologic period (i.e., the closer it is to the average condition). **Figure H-2** shows the ranking results of the 46 hydrologic years,

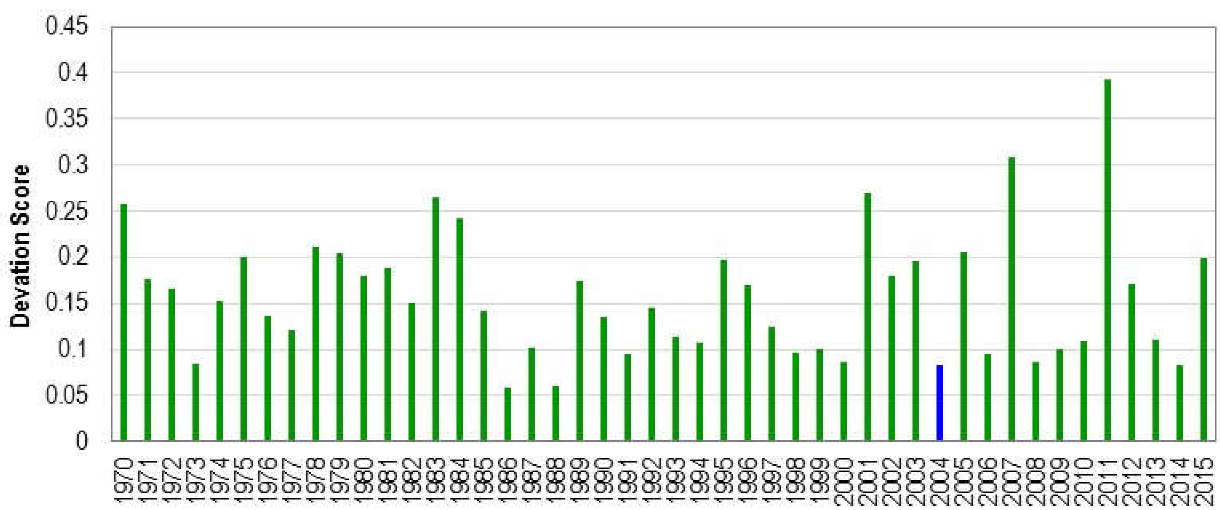


Figure H-2: Ranking Score of 1970-2015

H.2.3 Top Ranked Hydrologic Years

Table H-3 summarizes top 20 ranked years based on the ranking analysis. It was decided that a more recent period be used for the PVSC CSO LTCP study to reflect recent climate conditions. It was also determined that the typical year should be selected from years with an annual precipitation depth greater than the average value (highlighted with green background in **Table H-3**) to be more conservative. Therefore, the following five years are the top years to be considered for typical year selection:

- 1: 2004
- 2: 2014
- 3: 1973
- 4: 2008
- 5: 2006

Table H-3: Top 20 Ranked Years

Preliminary Rank	Year	Deviation Score	Annual Rainfall (in)	# of Events >=0.2" Rainfall Depth	# of Events >=0.1" Rainfall Depth	5th Largest Storm (in)	Rainfall Volume for 85% Captured (in)	# of back-to-back events	Maximum Peak Intensity of 5th Largest & Smaller	# of Storms with Return Freq > 1-yr	Average Rainfall Duration (hr)	Average Rainfall Intensity (in/hr)
		Weighing Factor	30%	10%	5%	5%	5%	10%	5%	5%	15%	10%
		Average 1970-2015	46.3	51.2	66	1.7	1.35	10.54	0.90	2.2	10.85	0.081
1	1986	0.058	46.0	52	67	1.77	1.43	13	0.76	2	11.03	0.072
2	1988	0.060	43.5	55	59	1.66	1.12	10	0.80	2	10.81	0.078
3	2004	0.082	48.4	54	73	1.63	1.18	12	0.99	3	10.33	0.084
4	2014	0.082	49.3	60	69	1.56	1.24	10	1.26	2	10.99	0.083
5	1973	0.084	46.3	50	61	2.15	1.27	7	0.72	2	11.77	0.082
6	2008	0.086	48.8	49	69	1.84	1.34	11	0.77	3	10.04	0.094
7	2000	0.086	43.4	49	63	1.43	1.02	10	0.50	2	10.24	0.081
8	2006	0.095	50.2	52	65	2.01	1.44	12	1.17	3	11.26	0.078
9	1991	0.096	43.8	54	64	1.95	1.33	5	0.88	2	11.03	0.084
10	1998	0.097	43.5	43	56	1.89	1.42	10	1.23	2	11.59	0.089
11	1999	0.099	44.8	52	60	1.43	1.82	11	0.65	3	11.92	0.076
12	2009	0.099	47.9	54	74	1.87	1.13	13	0.80	1	10.91	0.074
13	1987	0.101	45.5	54	64	1.61	1.07	12	0.97	0	11.39	0.079
14	1994	0.107	47.3	57	72	1.76	1.16	12	0.96	0	11.18	0.077
15	2010	0.108	43.5	44	52	1.60	1.51	10	0.93	2	12.08	0.103
16	2013	0.110	42.9	49	61	1.43	1.06	9	1.10	1	10.41	0.083
17	1993	0.114	42.5	50	60	1.65	1.07	10	0.80	1	12.60	0.074
18	1977	0.120	48.0	49	73	2.04	2.05	9	1.00	1	10.47	0.071
19	1997	0.125	42.4	45	60	1.35	1.21	7	0.71	2	10.75	0.066
20	1990	0.135	52.3	62	79	1.88	1.08	11	1.04	2	9.78	0.096

Rainfall return frequency was analyzed to understand the distribution of the large rainfall events with return frequencies above one year. **Table H-4** summarizes quantity of large rainfall events with return frequencies for the above-mentioned top ranked hydrologic periods.

Table H-4: Top 5 Ranked Years – Quantity of Rainfall Events

Final Rank	Year		Quantity of Rainfall Events with Return Frequency Above			
		1-yr	2-yr	5-yr	10-yr	50-yr
1	2004	2	1			
2	2014	1			1	0
3	1973	2				
4	2008	1	1	1		
5	2006	1		1		1

H.2.4 Selected Hydrologic Period

The year 2004 will be used as the typical hydrologic year for the CSO LTCP. The year 2004 was ranked first in the criteria described above and contains a wide range of storms and antecedent conditions. Year 2004 also has close to an average CSO volume and event number based on the hydrologic and hydraulic model results.

A summary of the parameters and the percent difference is shown below in **Table H-5**.

Table H-5: Summary of the Recommended Typical Year - 2004

Parameters	2004
Annual Precipitation*	48.37 in (4.5% greater than average 46.27)
Number of Events >=0.2" Rainfall Depth	54 (5% greater than average 51.2)
Number of Events >=0.1" Rainfall Depth	73 (11% greater than average 66)
5th Largest Storm Volume	1.63 in (5% less than average 1.70)
Rainfall Volume for 85% Capture	1.18 in (12% less than average 1.35)
Back-to-Back Storm Events	12 (14% greater than average 10.5)
Max Peak Intensity of 5th Largest Storm & Smaller	0.99 in/hr (9.5% greater than average 0.90)
Extreme Storm	1 Year Storm (2) 2 Year Storm (1)
Average Rainfall Duration	10.3 hr (4.8% less than average 10.8)
Average Rainfall Intensity	0.084 in/hr (3.8% greater than average 0.081)

Note:
* Includes snowfall

Characteristics of the top 20 rainfall events (by rainfall depth) in the hydrologic year are shown in **Table H-6**.

Table H-6: Top 20 Rainfall Events by Depth in 2004

2004	Event Start	Duration (hr)	Precipitation Depth (in)	Max Rainfall Intensity (in/hr)	Average Rainfall Intensity (in/hr)	Return Frequency
1	9/28/2004 1:00	28	**3.68**	0.53	0.13	2-yr – 24hr
2	9/8/2004 4:00	25	**2.21**	0.63	0.09	1-yr – 6hr
3	7/12/2004 9:00	27	**1.99**	0.32	0.07	
4	4/12/2004 17:00	30	**1.67**	0.25	0.06	
5	4/25/2004 14:00	35	**1.67**	0.25	0.05	
6	7/23/2004 10:00	24	**1.66**	0.33	0.07	
7	2/6/2004 5:00	33	**1.63**	0.33	0.05	
8	7/18/2004 16:00	14	**1.60**	0.64	0.11	
9	11/28/2004 2:00	12	**1.50**	0.85	0.13	
10	7/27/2004 15:00	18	**1.45**	0.41	0.08	
11	9/17/2004 22:00	12	**1.44**	1.33	0.12	1-yr – 2hr 2-hr – 1hr
12	6/25/2004 17:00	5	**1.39**	0.40	0.28	
13	11/12/2004 7:00	23	**1.08**	0.10	0.05	
14	5/12/2004 16:00	2	**1.08**	0.99	0.54	
15	11/4/2004 14:00	16	**1.03**	0.20	0.06	
16	7/5/2004 3:00	12	**1.00**	0.69	0.08	
17	12/1/2004 4:00	10	**1.00**	0.18	0.10	
18	8/16/2004 0:00	21	**0.94**	0.60	0.04	
19	8/21/2004 14:00	3	**0.84**	0.81	0.28	
20	12/6/2004 12:00	39	**0.83**	0.20	0.02	

SECTION I - HYDROLOGIC AND HYDRAULIC MODELING

I.1 BACKGROUND

An integrated PVSC collection system Hydrologic and Hydraulic (H&H) model is needed for the purpose of evaluating CSO control alternatives and developing a holistic CSO Long Term Control Plan (LTCP) for all the combined municipalities in the PVSC sewer service area.

Prior to this project/study, several H&H models were already developed using different modeling software platforms to simulate collection systems in several CSO communities. Detailed modeling information including communities, permittee, WRRF, and modeling software are summarized in **Table I-1**. The service area locations served by each individual models are shown in **Figure I-1**.

Table I-1: PVSC Pre-LTCP Model Summary

Model	Community	WWTP	Permittee	Software	County
PVSC Interceptor Model	City of Paterson	PVSC	Paterson City	InfoWorks CS	Passaic
	City of Newark	PVSC	Newark City		Essex
	Town of Kearny	PVSC	Town of Kearny		Hudson
	Borough of East Newark	PVSC	East Newark Borough		Hudson
	Town of Harrison	PVSC	Harrison Town		Hudson
Bayonne Model	City of Bayonne	PVSC	City of Bayonne	InfoWorks CS	Hudson
North Bergen Model (PVSC)	Township of North Bergen	PVSC	North Bergen MUA	PC-SWMM (2 models)	Hudson
Jersey City	City of Jersey City	PVSC	Jersey City MUA	XP-SWMM	Hudson
North Bergen (Woodcliff)*	Township of North Bergen	NBMUA Woodcliff	North Bergen MUA	PC-SWMM	Hudson
Guttenberg*	Town of Guttenberg	NBMUA Woodcliff	Town of Guttenberg	SWMM	Hudson

* North Bergen (Woodcliff) and Guttenberg areas will be discussed under a separate System Characterization Report.

The new integrated LTCP PVSC H&H model was developed by integrating four existing models into one complex PVSC model in InfoWorks ICM v7.5. The Jersey City model was not included in the model integration because it was determined that Jersey City would manage its own model. The four models used during LTCP PVSC model integration include the PVSC Interceptor model, the Bayonne model and the two North Bergen models. Brief descriptions of these four models are included in the following subsections.

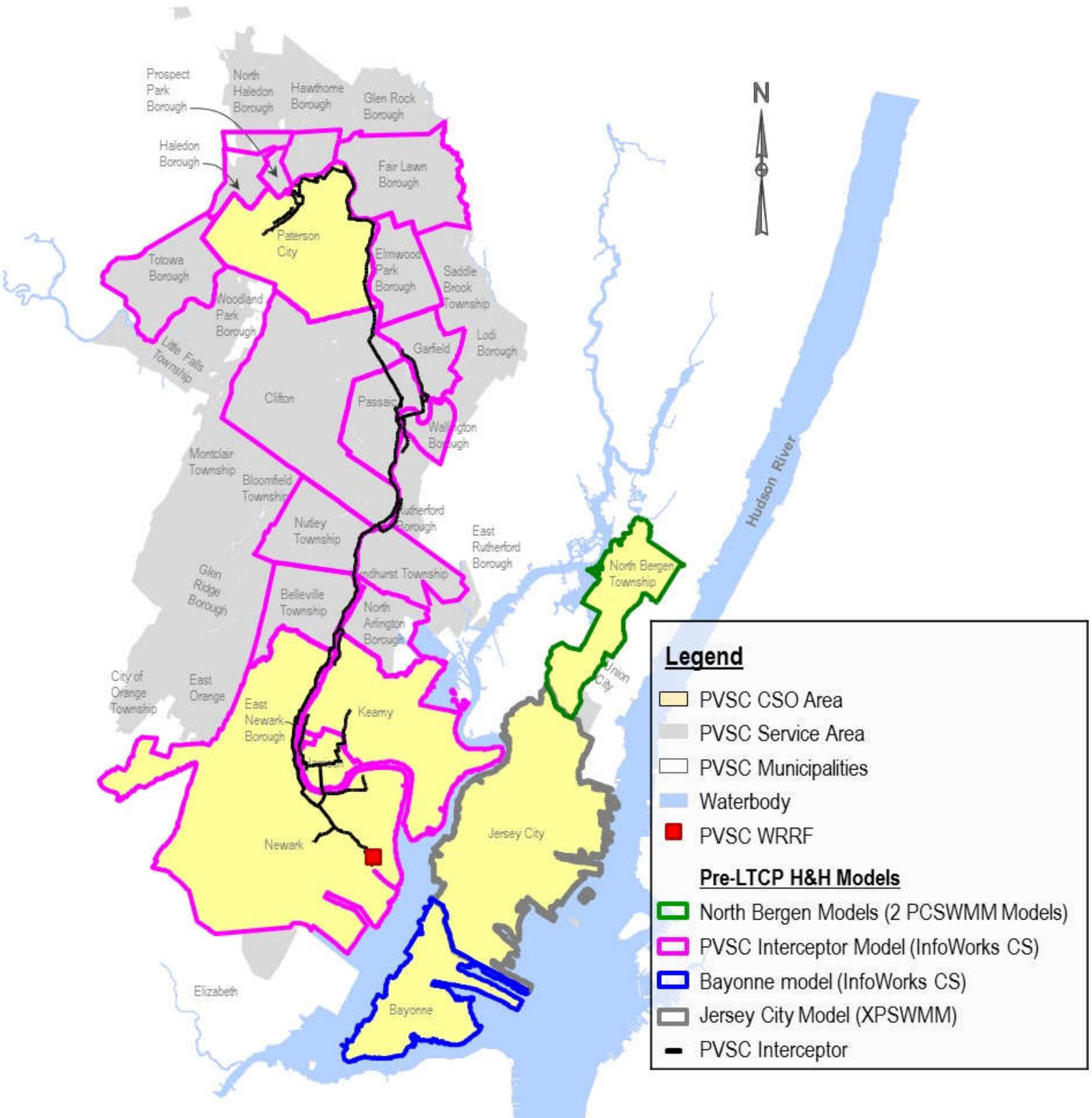


Figure I-1: Service Area Simulated in the PVSC Pre-LTCP Models

I.1.1 PVSC Interceptor Model

The received PVSC Interceptor Model is the largest of the four models used during model integration. **Figure I-2** shows its model network in InfoWorks CS. The model was lastly updated and calibrated by HDR in June 2016. It provides the backbone for the new integrated model. It simulates PVSC's service area west of the Newark Bay, including five of the eight combined sewer municipalities and seventeen separately sewered municipalities that are adjacent to and directly connected to the main interceptor. The five combined municipalities are the City of Patterson, the Borough of East Newark, the Town of Kearny, the Town of Harrison, and the City of Newark. And the separately sewered municipalities include Totowa, Haledon, North Haledon, Prospect Park, Hawthorne, Fair Lawn, Elmwood Park, Clifton, Garfield, Passaic, Wallington, Nutley, East Rutherford, Rutherford, Lyndhurst, North Arlington, and Belleville (municipalities are listed based on their geographical location from north to south). The corresponding service area simulated in the model are shown as the subcatchments in **Figure I-2** and the pink-highlighted areas in **Figure I-1**.

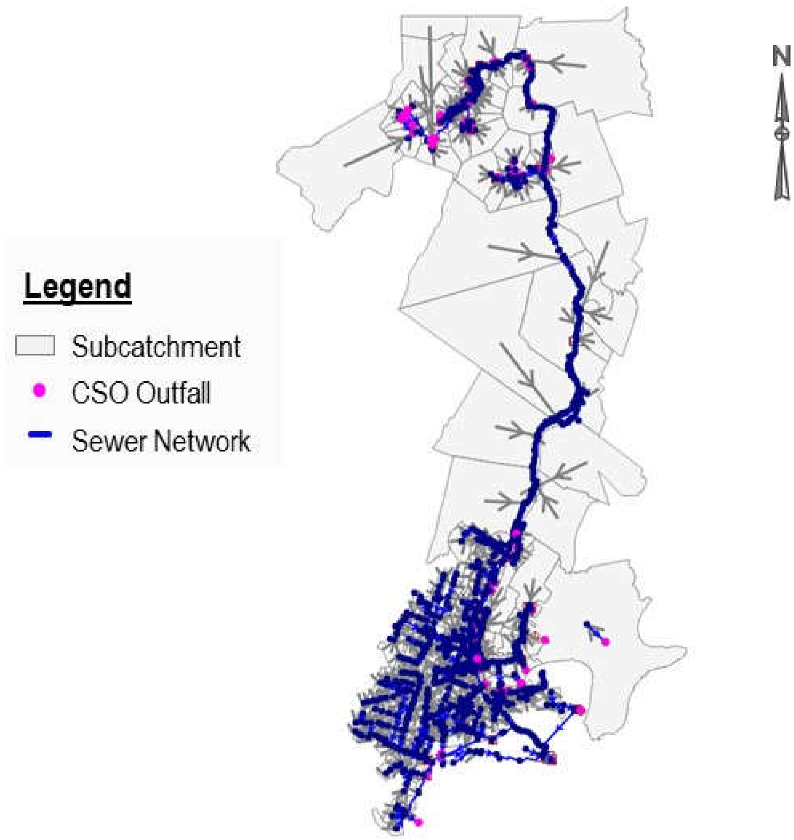


Figure I-2: Received PVSC Interceptor Model

The model did not include the Hudson County Force Main. Flow from the Hudson County Force Main was included as hourly inflow time series to allow the model to calculate total plant flow.

The operation of the plant main gates and regulated regulator gates in Newark were simulated with real time control (RTC) rules based on the actual operation logs.

The rainfall derived inflow and infiltration (RDII) for the separately sewered municipalities were simulated using the rational method (Q=CIA), where flow is a function of the drainage area, rainfall intensity and a runoff coefficient.

The PVSC Interceptor Model was created based on PVSC datum (the PVSC datum is 100 feet below Mean Sea Level (MSL) at Sandy Hook).

I.1.2 Bayonne Model

The Bayonne Model was received in March 2016 created in InfoWorks CS. The model was lastly updated by HDR/Mott MacDonald. **Figure I-3** shows its model network in InfoWorks CS. The model simulates the collection system in the City of Bayonne. The corresponding service area simulated in the model is shown as the subcatchments in **Figure I-3** and the blue-highlighted area in **Figure I-1**.

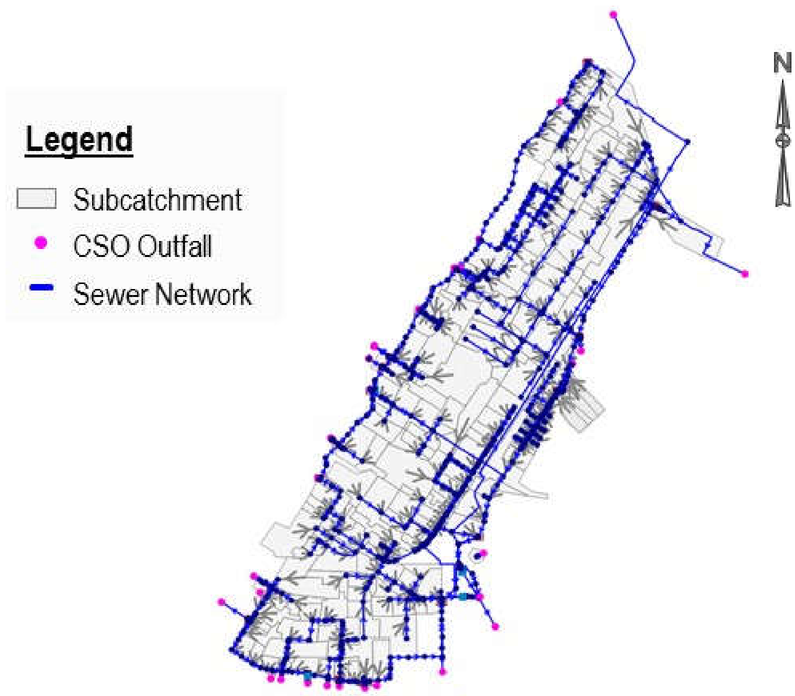


Figure I-3: Received Bayonne Model

City of Bayonne does not have its own sewer treatment facility. Sewers collected from its collection system are conveyed to the wet well at the Bayonne Pump Station at the Oak Street and pumped to the Hudson County Force Main, which conveys the combined flows from the Jersey City, the North Bergen and Bayonne to the PVSC WRRF for treatment. The Bayonne model ends at the Oak Street PS and Bayonne Force Main to the Jersey City.

The operation of eleven regulated regulator gates in Bayonne are simulated with real time control (RTC) rules based on the correlations between the gate opening and water depth.

The Bayonne Model was created based on MSL at Sandy Hook (the PVSC datum is 100 feet below MSL at Sandy Hook).

I.1.3 North Bergen Models

The two existing North Bergen models were received in March 2016. The models were lastly updated by Kleinfelder. Both of the two North Bergen models were originally created in PCSWMM; however, the received models were converted to EPA SWMM5 for the convenience of model integration in InfoWorks ICM. **Figure I-4** shows the model networks in EPASWMM. The subcatchments in the EPASWMM model are not GIS based, the corresponding service area simulated by these two models are shown in the green-highlighted areas in **Figure I-1**.

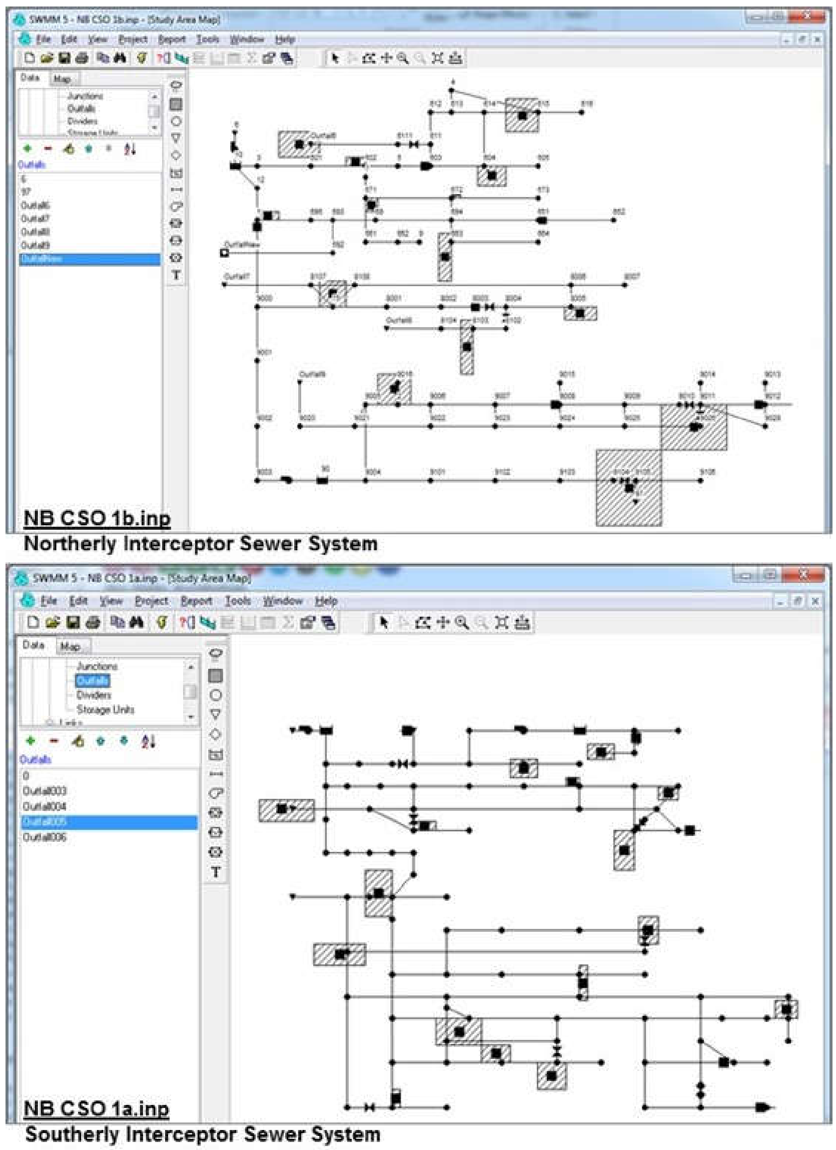


Figure I-4: Received North Bergen Model

North Bergen models are not GIS based, they are typical skeleton SWMM models developed in earlier days. There is no real time control rule set up for the regulator gates suggesting the gates were not regulated during wet weather conditions.

The North Bergen models were created based on the MSL at Sandy Hook (the PVSC datum is 100 feet below the MSL at Sandy Hook).

I.2 PVSC LTCP H&H MODEL INTEGRATION & DEVELOPMENT

The LTCP PVSC H&H model was developed by integrating the four existing models (the PVSC Interceptor model, the Bayonne model and the two North Bergen models) into one complex PVSC model in InfoWorks ICM v7.5. The model was then expanded to include all 40 municipalities with separate sewer service area that contributing flows to the PVSC WRRF.

I.2.1 Integration of PVSC Interceptor Model

The original PVSC Interceptor Model (InfoWorks CS) was integrated to the to the PVSC LTCP model (InfoWorks ICM) through a straight forward procedure of transferring data from CS to ICM. Most of the model network features remain the same during the transferring except the following major changes.

Paterson Re-delineation

The subcatchment boundaries in Paterson City was delineated based on Theissen polygons in the original PVSC Interceptor model. In order to better represent the actual drainage characteristics and sewer connectivity in the area, the subcatchments in the Paterson City were re-delineated based on GIS information of contours, sanitary sewer, storm sewer, etc. **Figure I-5** shows the Paterson City delineation before (orange polygon in **Figure I-5 (a)**) and after (blue polygon in **Figure I-5 (b)**) model integration. Subcatchments including red sewer lines are the separate areas.

Paterson Internal Regulator

There are 24 internal regulators in the Paterson City to relief extreme wet weather flows to storm sewers connecting to CSO outfall points. Typically the internal regulator conveys dry weather flow and a portion of wet weather flow to the PVSC Interceptor (through downstream CSO regulator). During larger storm events overflow would occur when the water surface level in the internal regulator is above its overflow weir crest. The extreme wet weather flows are conveyed to a storm sewer connecting to a CSO outfall. The description of individual internal regulators is detailed in **Table I-2**. **Table I-3** summarizes internal regulators in the area and their corresponding downstream CSO regulators and overflow CSO outfalls.

Figure I-6 (a) shows model network around the internal regulators (highlighted with the dashed red lines) in the original PVSC Interceptor Model. The conveyance of flows from the internal regulator overflow weir to CSO outfall are not included. Instead, artificial outfalls were created and connected to the overflow weirs. In the integrated PVSC LTCP Model, the artificial outfalls were removed, and the model network of manholes and sewers were extended from the internal regulator overflow weirs to CSO outfalls based on sewer GIS data and actual sewer connectivity shown in **Table I-2** and **Table I-3**. **Figure I-6 (b)** shows the updated model network in the integrated model.

Table I-2: Paterson Internal Regulator Description

Outfall # or Internal Regulator #	Location	Description
Outfall 028	**S.U.M. Park 2**	**120 " RCP**
A1-1	Westside Park	Side overflow weir with 36" RCP pipes in and out. Normal flow (including dry weather flow and a small portion of wet weather flow) discharges to 36" pipe flowing south cross the Passaic River, and then to the PVSC interceptor at CSO-001A. Wet weather overflow is through a 36" pipe to a 69" storm sewer connecting to CSO-028A.
A1-2	Union. & Sherwood Ave.	Side overflow Weir - Plugged
A1-3	Sherwood Avenue	Side overflow weir with 30" RCP pipes in and out. Normal flow discharges to 30" pipe passing to the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through a 24" pipe to a 90" storm sewer connecting to CSO-028A.
A1-4	Linwood. & Crosby Ave.	Side overflow weir at the bench with 18" VCP pipes in and 12 "out. Normal flow discharges to 12" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through an 18" pipe to a 30" storm sewer connecting to CSO-028A.
A1-5	Linwood. & Chamberlain Ave.	Side overflow weir at the bench with 12" & 24" VCP pipes in and 18" out. Normal flow discharges to 18" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through a 12" pipe to a 30" storm sewer connecting to CSO-028A.
A1-6	Richmond & Crosby Avenue	Side overflow weir at the bench with 12" ACP pipes in and out. Normal flow discharges to 12" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through a 12" pipe to 90" storm sewer connecting to CSO-028A.
A1-7	Crosby. & Emerson Ave.	Side overflow weir at the bench with 12" VCP pipes in and out. Normal flow discharges to 12" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through a 12" pipe to 60" storm sewer connecting to CSO-028A.
A1-8	Crosby. & Maitland Ave.	Side overflow weir at the bench with 10" & 12" VCP pipes in and 12" out. Normal flow discharges to 12" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through an 18" pipe to 60" storm sewer connecting to CSO-028A.
A1-9	Richmond Avenue between Crosby and Chamberlain	Side overflow weir at the bench with 10" & 12" VCP pipes in and 12" out. Normal flow discharges to 12" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through an 18" pipe to 60" storm sewer connecting to CSO-028A.
Outfall 029A	**Loop Road**	Twin 108" RCP, each pipe fitted with dual upturned flow diffusers at the outfall point
EF-2	Van Houten Street	An incoming 18" VCP pipe is regulated by a 7.5"H x 9.75"W gate and a side overflow weir. Normal flow discharges to a 15" VCP connecting to the PVSC interceptor at CSO-006A. Wet weather overflow is through a 36" RCP storm sewer connecting to CSO-029A.

Outfall # or Internal Regulator #	Location	Description
EF-3	Ellison Street	An incoming 36" VCP pipe is regulated by a 7.5"H x 15.75"W gate and a side overflow weir. Normal flow discharges to an 18" VCP connecting to the PVSC interceptor at CSO-006A. Wet weather overflow is through a 48" RCP storm sewer connecting to CSO-029A.
EF-4	Market Street	An incoming 48" RCP is regulated by a 12"H x 12"W gate and a side overflow weir. Normal flow discharges to an 18" VCP connecting to the PVSC interceptor at CSO-006A. Wet weather overflow is through a 48" RCP storm sewer connecting to CSO-029A.
EF-5	Market Street	An incoming 18" VCP is regulated by a 5"H x 9.25"W gate and a side overflow weir. Normal flow discharges to a 12" VCP connecting to the PVSC interceptor at CSO-006A. Wet weather overflow is through a 30" RCP storm sewer connecting to CSO-029A.
EF-6	Railroad Ave and Grand Street	An incoming flow is in a 77"H x 121"W concrete box culvert and is regulated by a 16"H x 27.5"W gate and a side overflow weir. Normal flow discharges to a 36" RCP connecting to the PVSC interceptor at CSO-006A. Wet weather overflow is through a 120" RCP storm sewer connecting to CSO-029A
Outfall 030	**Nineteenth Avenue**	**90 " RCP**
V2-1	19th Avenue Regulator	An incoming 70.5"H x 85"W brick pipe is regulated by two (2) 19.25' long side overflow weirs with mechanical solids/floatables screening. Normal flow discharges to a 70.5"H x 85"W brick pipe connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 90" RCP storm sewer connecting to CSO-030A.
Outfall 031	**Route 20 Bypass**	**120 " RCP**
V1-1	23rd & Trenton Avenue	An incoming 15" VCP pipe is regulated by a 2.5' long side overflow weir. Normal flow discharges to a 15" VCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 42" RCP storm sewer connecting to CSO-031A.
V1-2	22nd & Trenton Avenue	An incoming 15" VCP pipe is regulated by a 5' long side overflow weir. Normal flow discharges to a 15" VCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 42" RCP storm sewer connecting to CSO-031A.
V1-3	Trenton Avenue between 22nd & 21st	Two incoming 8" VCP pipes are regulated by a side overflow weir. Normal flow discharges to a 12" pipe connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 10" VCP to a 30" RCP storm sewer connecting to CSO-031A.
V1-4	Maryland Avenue	Three incoming pipe (10" VCP, 12" VCP, and 30" RCP) are regulated by a 10' long side overflow weir. Normal flow discharges to a 30" RCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 102" RCP storm sewer connecting to CSO-031A.
V1-5	Trenton & Maryland Avenue	Two incoming pipe (24" RCP) are regulated by a 9' long side overflow weir. Normal flow discharges to a 30" pipe connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 102" RCP storm sewer connecting to CSO-031A.
V1-6	Trenton & Florida Avenue	An incoming 24" RCP pipe is regulated by 9' long side overflow weir. Normal flow discharges to a 24" RCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through an 84" RCP storm sewer connecting to CSO-031A.

Outfall # or Internal Regulator #	Location	Description
V1-7	Trenton & Illinois Avenue	An incoming 24" RCP pipe is regulated by 11' long side overflow weir. Normal flow discharges to a 24" RCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through an 84" RCP storm sewer connecting to CSO-031A.
V1-8	Trenton & Michigan Avenue	An incoming 24" RCP pipe is regulated by an 18' long side overflow weir with mechanical solids/floatables screening. Normal flow discharges to a 24" RCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 60" RCP storm sewer connecting to CSO-031A.
V1-9	Alabama & E. Railway Avenue	An incoming 30"x42" Brick pipe is regulated by a 16' long side overflow weir with mechanical solids/floatables screening. Normal flow discharges to a 36" RCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 54" RCP storm sewer connecting to CSO-031A.
Outfall 033A	**Tyler Street /Washington Street**	**Outfall is direct to Passaic River at CSO-033A**
EF-1	River Street	An incoming 48" RCP is regulated by a 7.5"H x 12.375"W gate with a side overflow weir. Normal flow discharges to a 15" VCP connecting to the PVSC interceptor at PVSC MH243. Wet weather overflow is through a 48" RCP storm sewer connecting to CSO-033A.

Table I-3: Paterson Internal Regulator Downstream Flow Conveyance

Regulator #	Normal Flow	Overflow
A1-1 to A1-9 (8)	P_001A Regulator	P_028A
EF-2 to EF-6 (5)	P_006A Regulator	P_029A
V2-1	P_027A Regulator	P_030A
V1-1 to V1-9 (9)	P_027A Regulator	P_031A
EF-1	PVSC Interceptor MH 243	P_033A

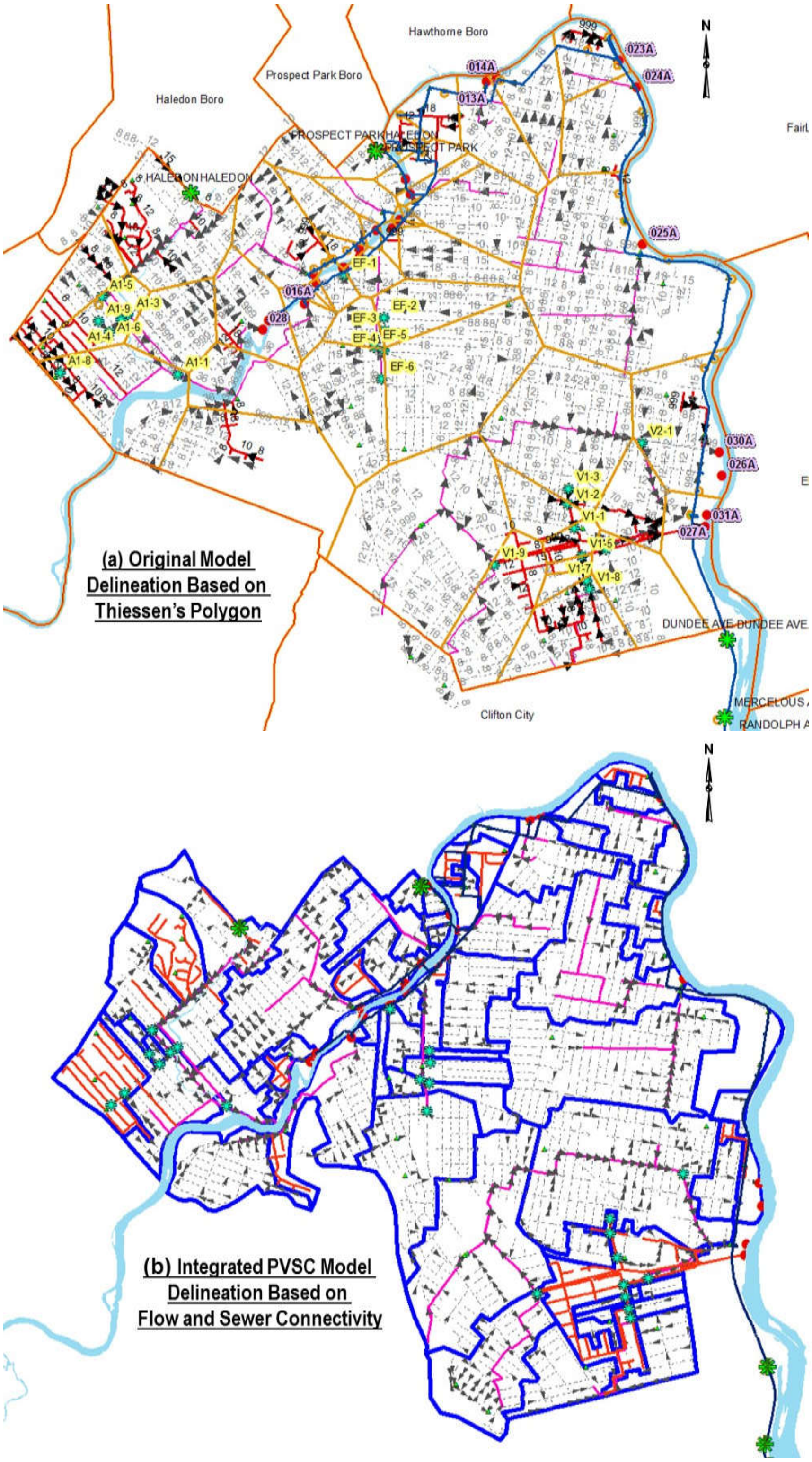


Figure I-5: Subcatchment Re-delineation of Paterson City

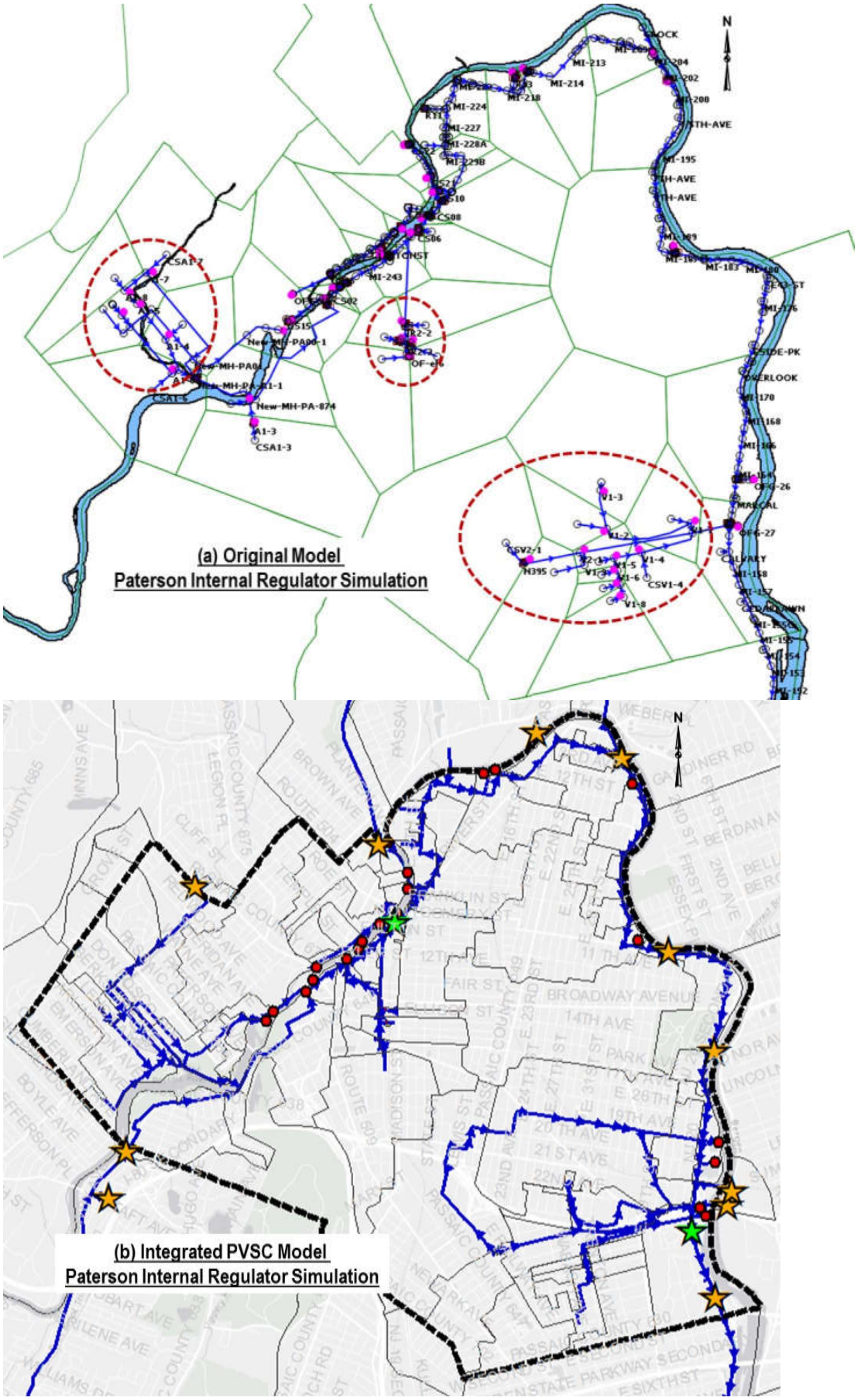


Figure I-6: Paterson City Internal Regulator Simulation

Model Network of the CSO Municipalities in the Integrated PVSC Model

There are five CSO municipalities included in the original PVSC Interceptor Model: Paterson, Newark, East Newark, Kearny, and Harrison. Model network of these five municipalities in the integrated model are shown in **Figure I-7** through **Figure I-11**. Quantities of subcatchments, nodes and links are also shown in the map. Permanent meters and temporary meters indicated in the map are the meters used for model calibration.

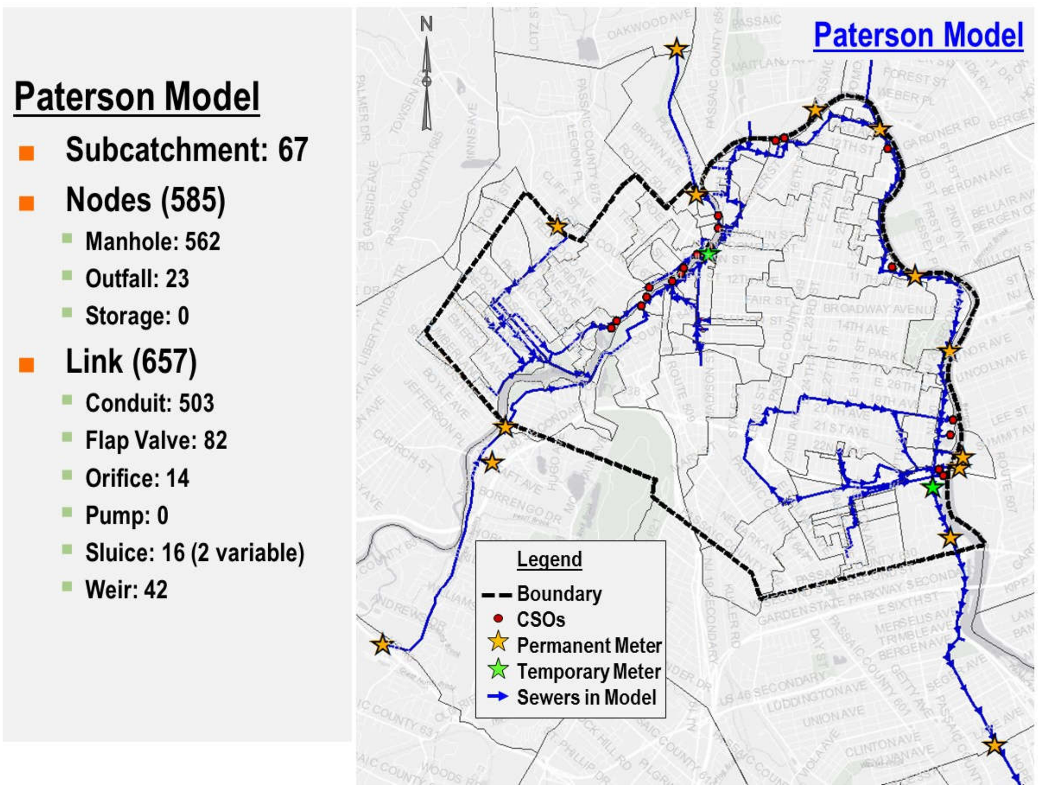


Figure I-7: Snapshot of Model Network in Paterson

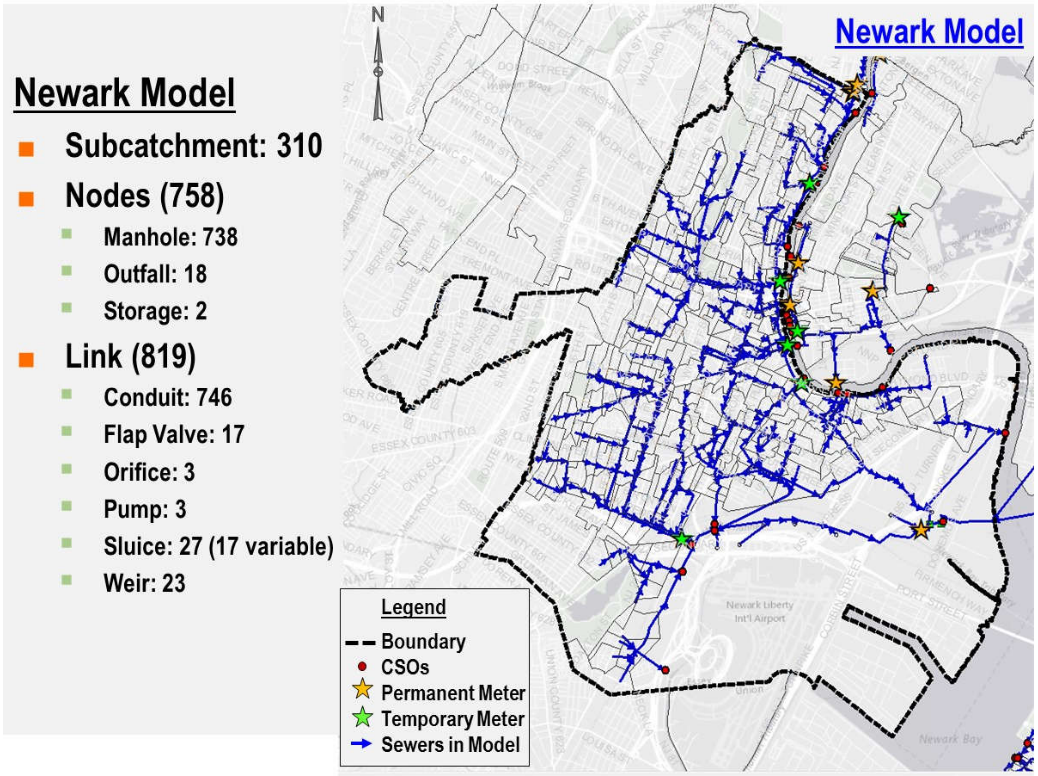


Figure I-8: Snapshot of Model Network in Newark

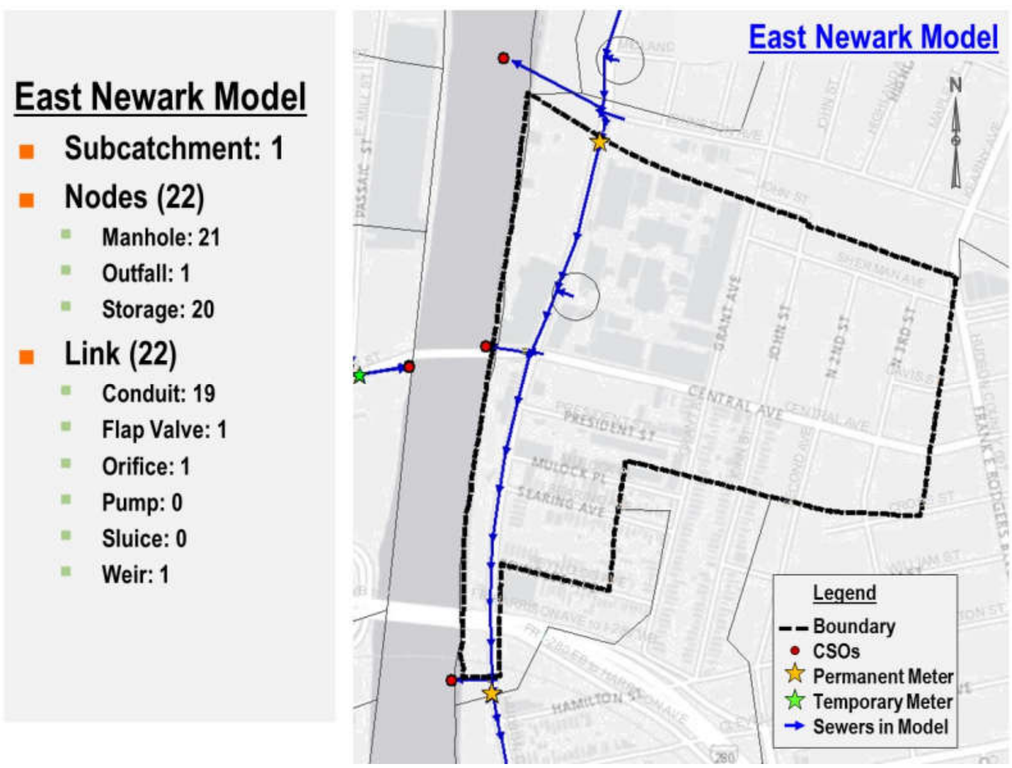


Figure I-9: Snapshot of Model Network in East Newark

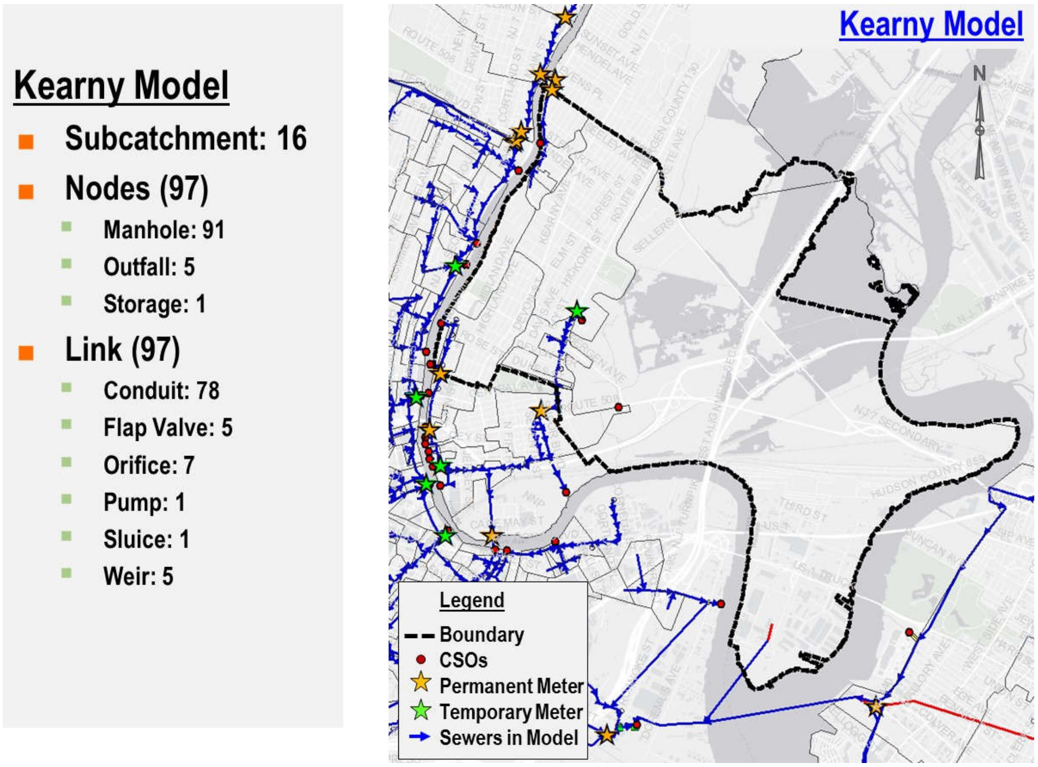


Figure I-10: Snapshot of Model Network in Kearny

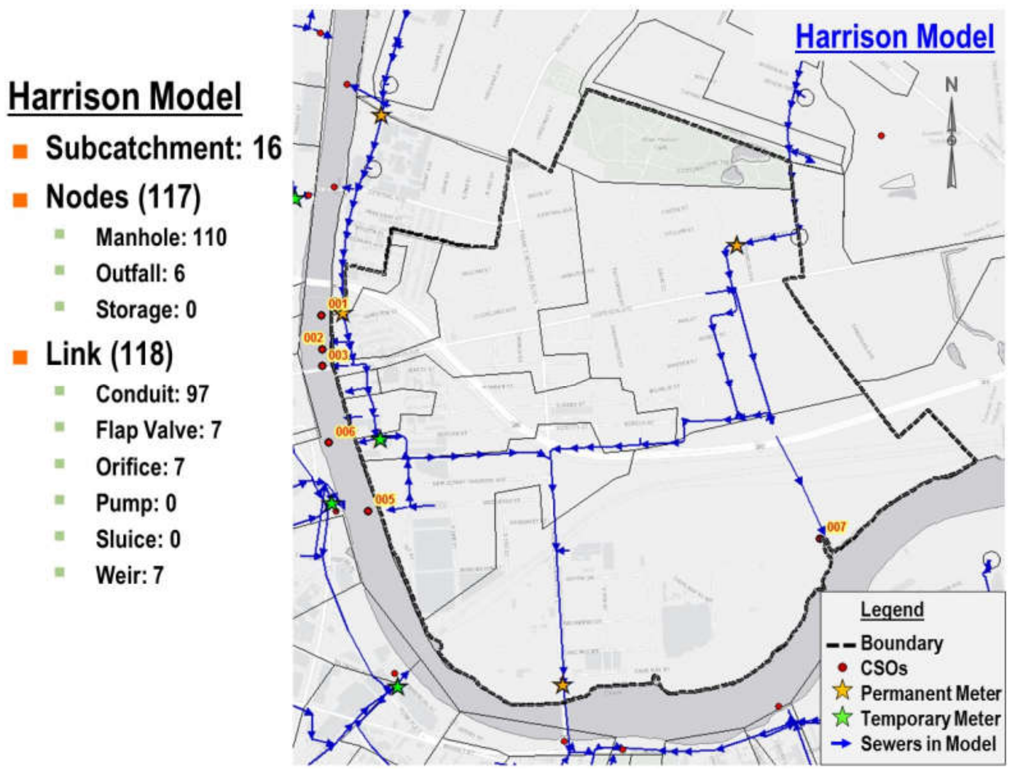


Figure I-11: Snapshot of Model Network in Harrison

I.2.2 Integration of Bayonne Model

The original Bayonne Model (InfoWorks CS) was integrated to the to the PVSC LTCP model (InfoWorks ICM) through a straight forward procedure of transferring data from CS to ICM. All of the model network features remain the same during the transferring except the following minor changes.

- Updated IDs of subcatchments, nodes and links to start with “BA-”
- All Real Time Controls (RTCs) were appended to the integrated model.

  The eleven RTCs are used to control regulator gate openings based on the water levels. **Table I-4** shows the level-opening table prior to and post model integration. The “output” column in the table is corresponded to the regulator gate opening with a default unit of “meter”. The values used in the “output” column in the original Bayonne model are corresponded to the unit of “feet”, which should be converted to “meter”. This is completed for all the eleven RTC tables in the integrated model.
- Updated datum from the MSL to PVSC datum
- Extended the 36” Bayonne force main from the municipality boundary to the Jersey City West Pump Station to connect to the Hudson County Force Main.

Model network of Bayonne City in the integrated model is shown in **Figure I-12**. Quantities of subcatchments, nodes and links are also shown in the map. Permanent meters and temporary meters indicated in the map are the meters used for model calibration.

Table I-4: Bayonne RTC Table Update

	Original Bayonne Model		Integrated PVSC Model	
	Input (ft)	Output	Input (ft)	Output
B1A-R011.S	0	0.625	0	0.190
	0.751	0.313	0.751	0.095
	1.499	0	1.499	0.000
BA-R014.S	0	1	0	0.305
	1.749	0.5	1.749	0.152
	3.501	0	3.501	0.000
BA-R018.S	0	1.33	0	0.405
	1.749	0.665	1.749	0.203
	3.501	0.665	3.501	0.203
BA-R003.S	0	1	0	0.305
	2.251	0.5	2.251	0.152
	4.501	0.5	4.501	0.152
BA-R006.S	0	1	0	0.305
	1.499	0.5	1.499	0.152
	2.999	0.5	2.999	0.152
BA-R008.S	0	0.625	0	0.190
	1.25	0.313	1.25	0.095
	2.5	0.313	2.5	0.095
BA-R009.S	0	1	0	0.305
	1.001	0.5	1.001	0.152
	2.001	0.5	2.001	0.152
BA-R010.S	0	0.417	0	0.127
	0.499	0.209	0.499	0.064
	1.001	0.209	1.001	0.064
BA-R012.S	0	1.083	0	0.330
	1.001	0.542	1.001	0.165
	2.001	0	2.001	0.000
BA-R015.S	0	0.417	0	0.127
	1.749	0.209	1.749	0.064
	3.501	0	3.501	0.000
BA-R017.S	0	1	0	0.305
	1.375	0.5	1.375	0.152
	2.749	0	2.749	0.000

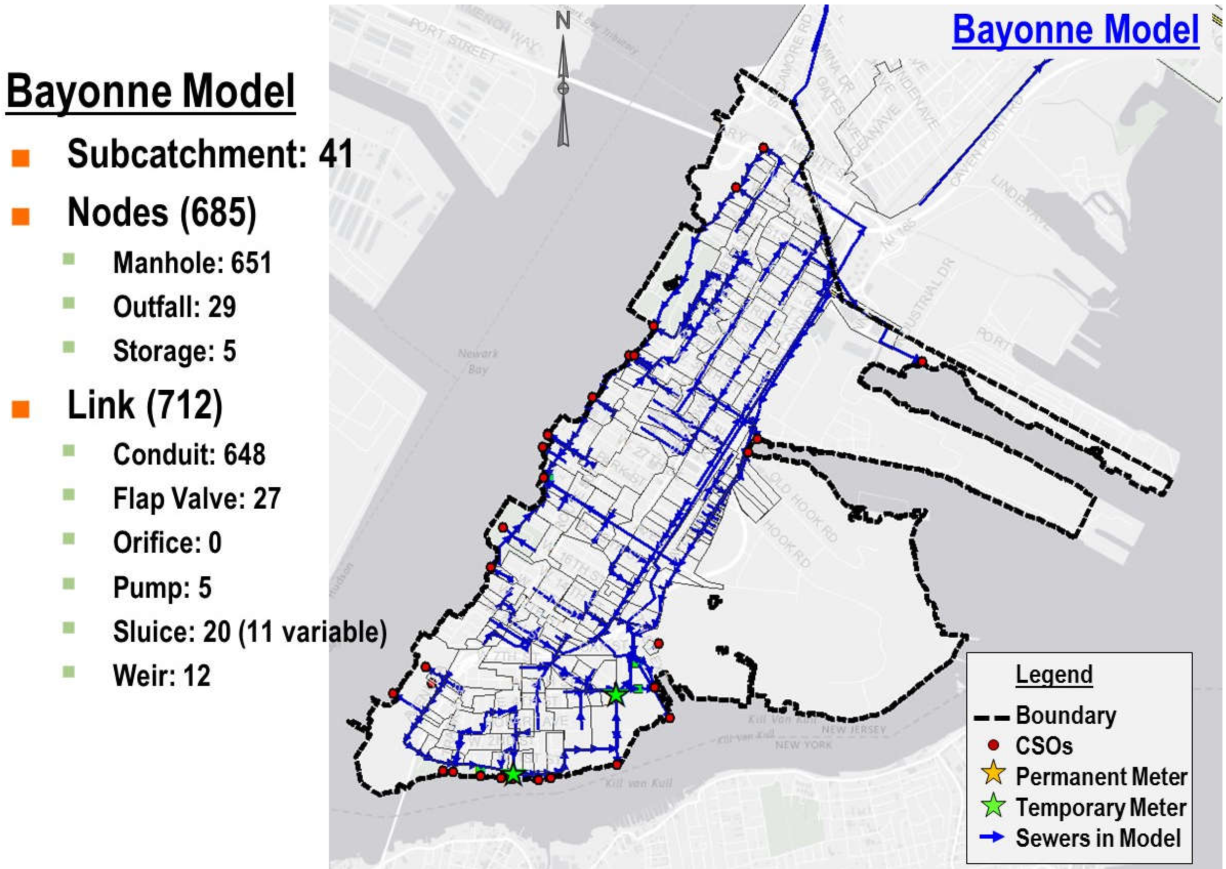


Figure I-12: Snapshot of Model Network in Bayonne

I.2.3 Integration of North Bergen Model

The two received North Bergen models (**Figure I-4**, EPASWMM, one for north side and the other for the south side) were imported to the InfoWorks ICM. This import is to obtain the input information for subcatchment, node and link for the integrated ICM model. The model network (including subcatchments, nodes, and links) is not GIS based, therefore more efforts were made to prepare GIS based model network for North Bergen.

North Bergen Subcatchments

A paper copy of the North Bergen subcatchment delineation was obtained from the modeling document "Adaptation of SWMM to Simulate the Combined Sewer Overflows of the North Bergen MUA" (January 2007, by Najarian Associates). The paper copy was used to prepare a digitized a polygon shape file in the GIS to represent subcatchments (**Figure I-13**). The subcatchment ID was assigned to the polygons according to the acreage information in the model document (**Figure I-14**). The subcatchment shape file was then incorporated into the integrated model through "Data Import Centre".

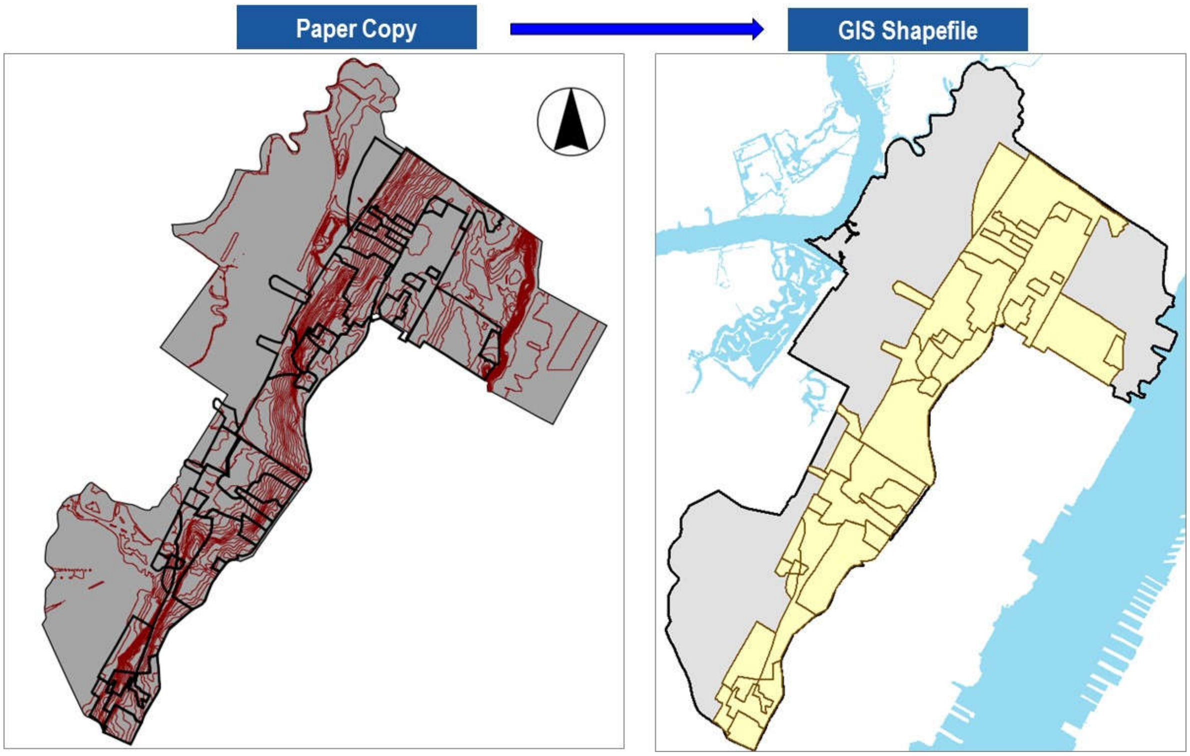


Figure I-13: Digitizing Model Subcatchment Based on Paper Copy

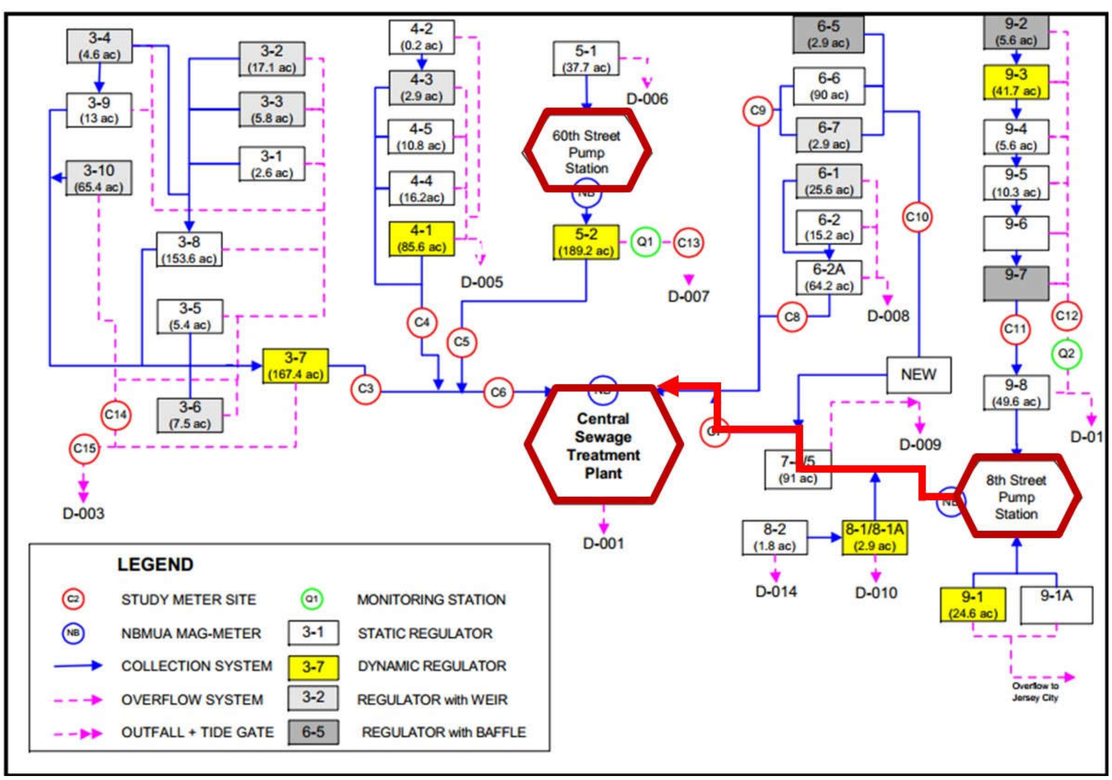


Figure I-14: Model Schematics from Previous Modeling Document

North Bergen Sewer Network

The North Bergen manholes and sewers to be included in the integrated model were selected based on sewer connectivity shown in GIS shape files (**Figure I-15**) and schematic sewers shown in the EPASWMM model (**Figure I-4**). The selected manholes and sewers were then incorporated into the integrated model through "Data Import Centre".

Detail sewer data (invert, dimension, etc.) and manhole data (invert, rim elevation, etc.) were not available from the sewer GIS file, therefore the invert and pipe size information from the received EPASWMM model were used for the integrated model.

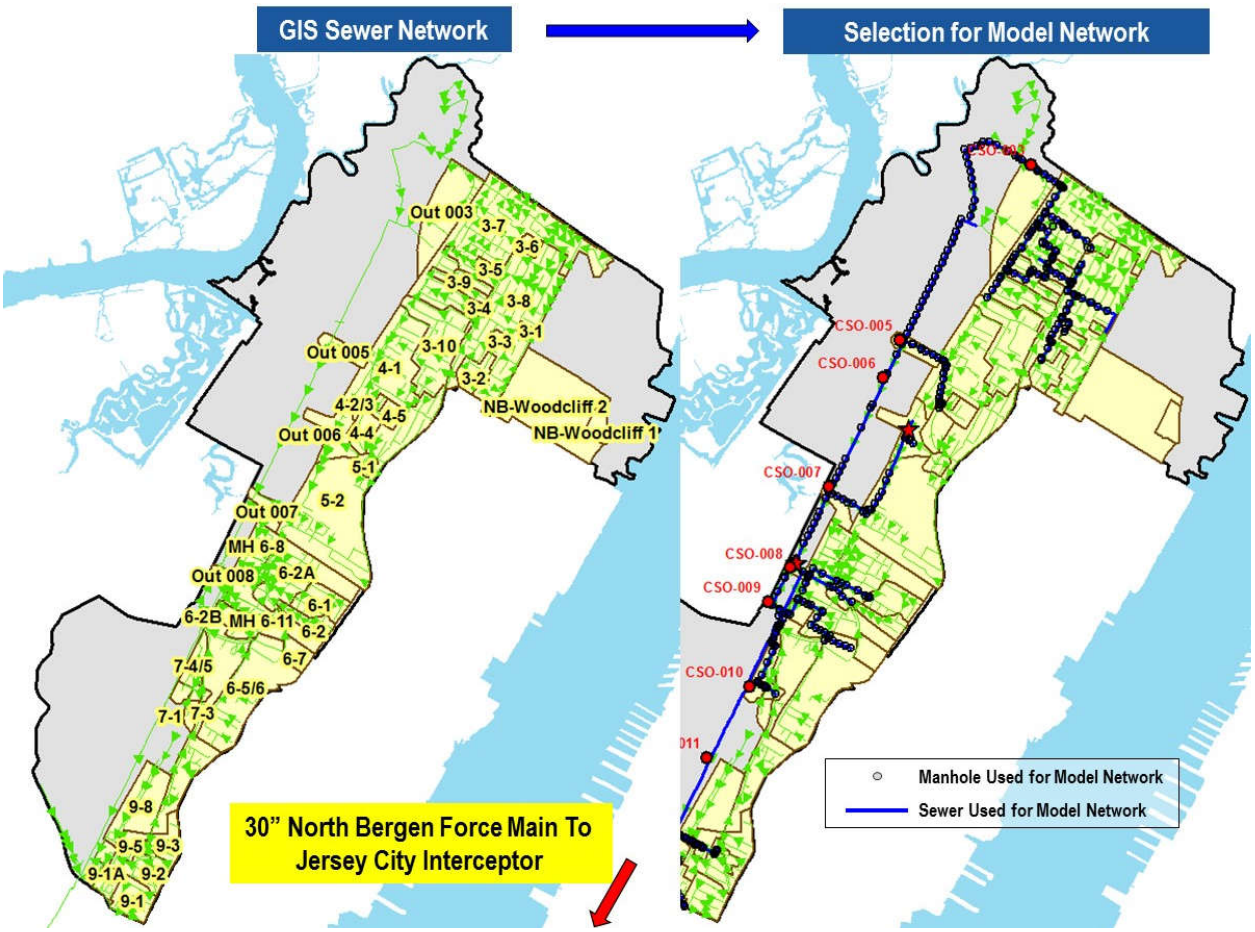


Figure I-15: Selected Manhole and Sewers for Model Network

North Bergen Sewer Connectivity Update

In the received model, the 8th Street Pump Station pumps flow to the downstream sewer system. The joined pumped flow and local flow are conveyed to the Central Sewage Treatment Plant by gravity (**Figure I-14**). In 2010, the Central Sewage Treatment Plant was decommissioned and the Central Pump Station were built to convey flows from North Bergen to Jersey City through a 30-in force main. With the decommission of the Central Sewage Treatment Plant, the 8th Street Pump Station no longer pumps flow to the downstream gravity sewer mains, instead, it pumps flow to the 30-in force main. Flows from North Bergen are conveyed through the Jersey City's gravity sewer mains to the Jersey City West Pumping Station (JCWP). The JCWP pumps flows through the Hudson County Forcemain to the primary clarifier at the PVSC treatment plant.

The updated flow schematics shown in **Figure I-16** is incorporated into the integrated model.

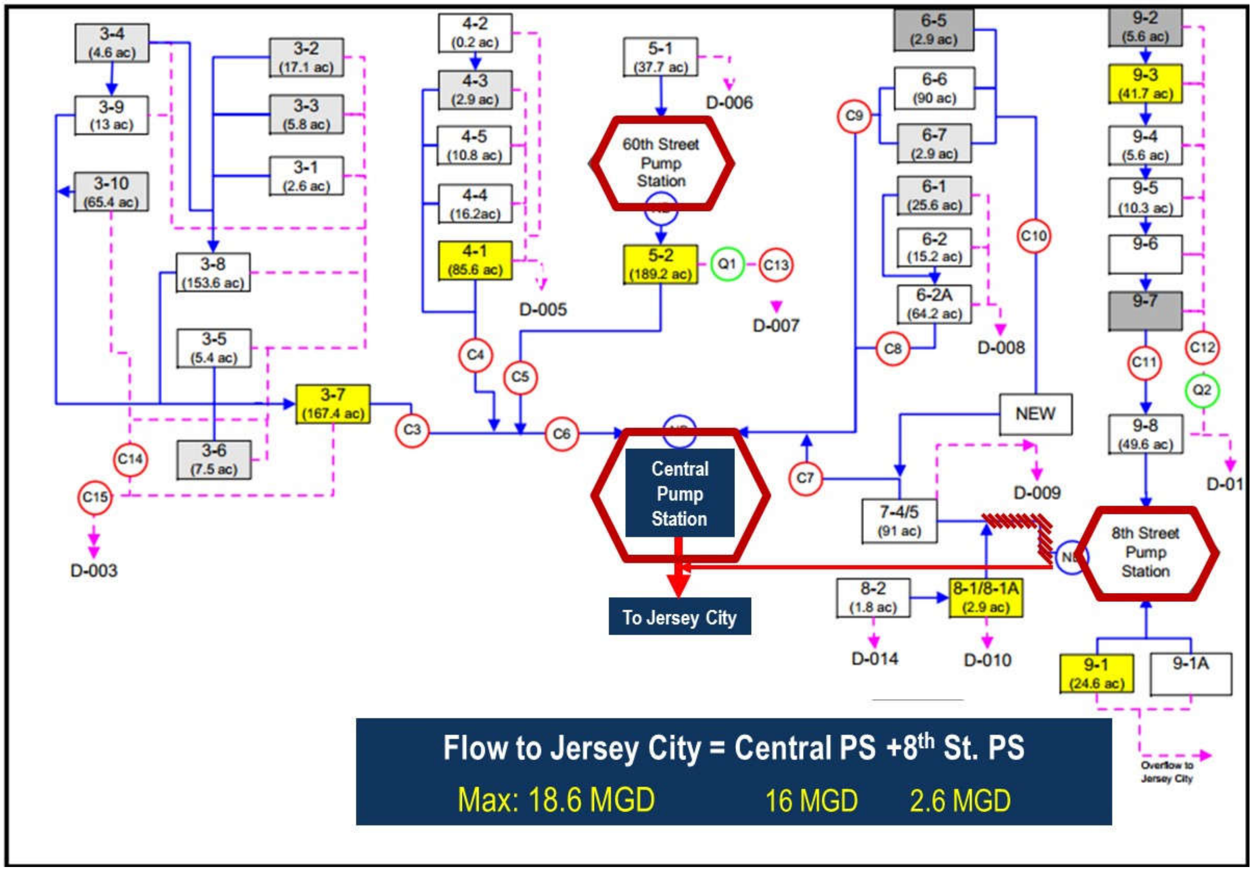


Figure I-16: Updated North Bergen Model Schematics

North Bergen in the Integrated Model

In a summary, the integration of the North Bergen includes the following major steps:

- Updated IDs of subcatchments, nodes and links to start with "NB1A-" or "NB1B-"
- Model inputs are mostly derived from the received EPASWMM model
- Subcatchment and model network were updated to GIS-based
- Updated sewer network connectivity due to the decommission of the Central Sewer Treatment Plant
- Converted dry weather inputs to subcatchment inflows
- Added North Bergen Central Pump Station
- Updated pump curves based on received information for the 8th Street PS, 60th Street PS, and the North Bergen Central PS

- Updated datum from the MSL to PVSC datum
- Added the 30” North Bergen force main between the Central Pump Station and Jersey City Sewer System

Model network of North Bergen in the integrated model is shown in **Figure I-17** (not including the area draining to the Woodcliff Treatment Plant). Quantities of subcatchments, nodes and links are also shown in the map. Permanent meters and temporary meters indicated in the map are the meters used for model calibration.

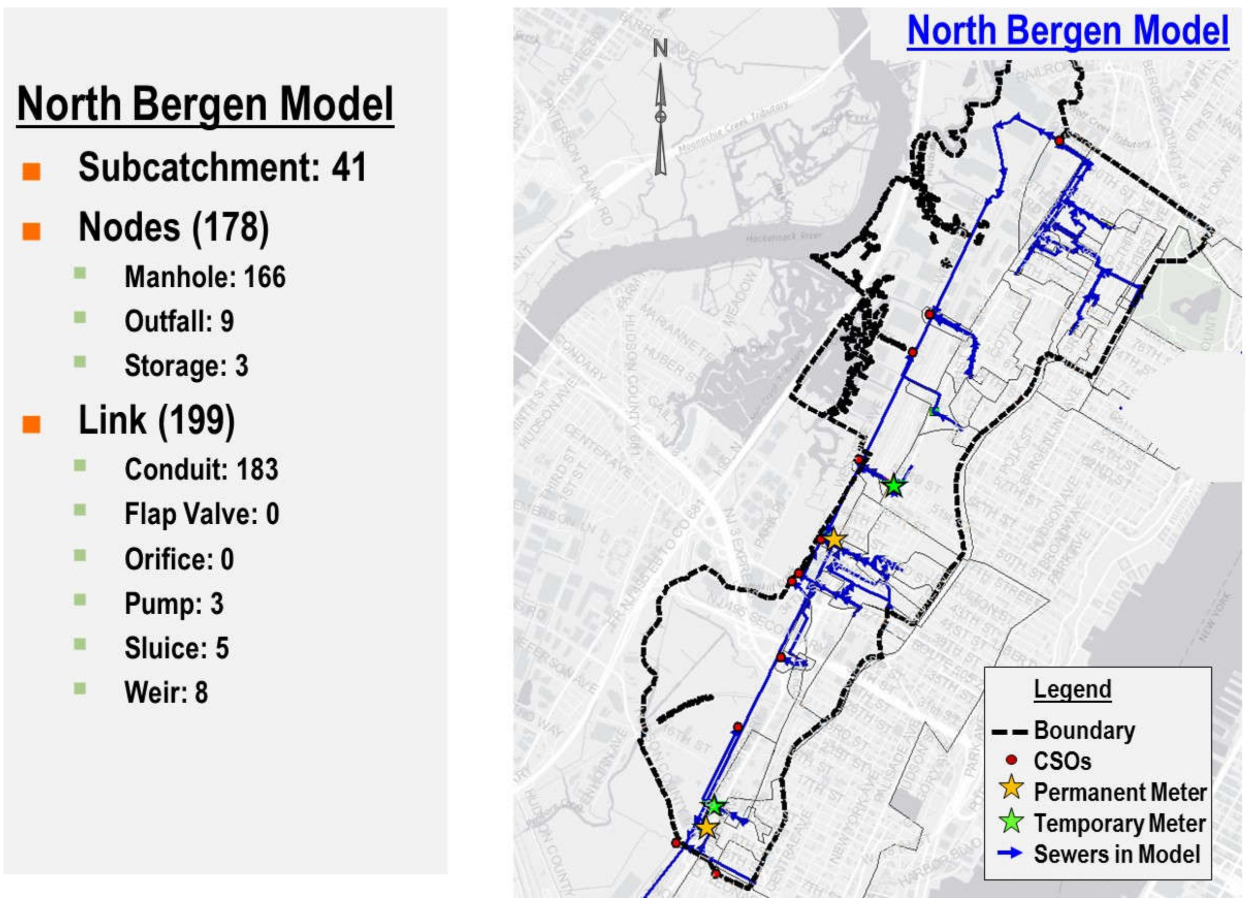


Figure I-17: Snapshot of Model Network in North Bergen

I.2.5 Model Expansion to Whole Service Area

The above mentioned model integration is able to incorporate all the communities with combined sewer systems except Jersey City in the same model, including

- Paterson (Passaic County)
- Newark (Essex County)
- East Newark (Hudson County)
- Kearny (Hudson County)
- Harrison (Hudson County)
- North Bergen (Hudson County), and
- Bayonne (Hudson County)

Model integration also brought a portion of the PVSC separate sewerd communities in the system from the PVSC Interceptor Model (**Figure I-1**), including

- Totowa, Haledon, North Haledon, Prospect Park, Hawthorne, Clifton and Passaic from the Passaic County,
- Fair Lawn, Elmwood Park, Garfield, Wallington, Rutherford, East Rutherford, Lyndhurst, and North Arlington from the Bergen County, and
- Nutley and Belleville from the Essex County.

The integrated model was then expanded to include all PVSC served separate sewer communities. The newly added separate sewer communities are shown in **Figure I-18**, including

- Franklin Lakes, Woodland Park, Little Falls, North Caldwell, and Cedar Grove from the Passaic County,
- Ridgewood, Glen Rock, Saddle Brook, Lodi, South Hackensack, Hackensack, Wood-Ridge, and Hasbrouck Height from the Bergen County,
- Montclair, Glen Ridge, Bloomfield, City of Orange, East Orange, West Orange, South Orange, and Hillside from the Essex County, and
- Elizabeth City from Union County.

Communities simulated in the final PVSC model are shown in the schematic **Figure I-19**.

I.2.6 Model Evaluation Group (MEG) Review

A Model Evaluation Group (MEG) comprised of recognized experts in hydrologic, hydraulic, hydrodynamic, and water quality monitoring and modeling was formed to provide technical review and guidance. The MEG was comprised of the following individuals:

- Dr. Alan Blumberg, Stevens Institute of Technology;
- Dr. Steve Chapra, Tufts University; and
- Dr. Wayne Huber, Oregon State University.

The MEG's stated mission was as follows:

> *"The Model Evaluation Group (MEG) will review all significant technical aspects of the PVSC Long Term Control Plan model development. Model development will consist of three distinct components: Landside, Hydrodynamic, and Water Quality. The goal is to ensure that these model components are technically viable for use by the engineering team in the assessment of engineering alternatives and with withstand regulatory and public scrutiny.*
>
> *The MEG will provide guidance, where appropriate, to improve or enhance the approaches and methodologies that lead to model development. The MEG will judge, individually and jointly, the technical acceptability of the major model components. If a component is deemed unacceptable, the MEG will outline steps to improve the technical acceptability of the model components."*

Workshop meetings with the MEG, PVSC and their consultants, and the New Jersey Department of Environmental Protection to discuss the development and use of each of the models, as well as to receive feedback and input regarding the monitoring and modeling work. These meetings were held on the following dates:

- February 5, 2016;
- March 17, 2017; and
- September 15, 2017.

The MEG provided various comments related to the updating, calibration, and validation of the hydrologic and hydraulic model. The below **Table I-5** is a summary of key related comments and how the model was configured to address or respond to these comments:

Table I-5: Summary of MEG Comments and Responses

MEG Session	MEG Comments	Responses
Session 1 Feb 5, 2016	It might be useful to sample sediment in the interceptor if it has sedimentation issues.	We will not sample sediment quality in sewers, but will measure sediment depths at flow metering sites
	Interceptor geometry is critical for hydraulic grade line determination.	The existing local models and the PVSC interceptor model represent geometry adequately in all major pipes. The integrated PVSC model has incorporated good representation of the geometry of all pipes.
	Infiltration/inflow (I/I) was discussed, but monitoring of sanitary sewers was not adequately described. Will I/I just get merged with downstream sanitary sewage for estimating bacteria concentrations?	PVSC already monitors incoming flows from each of its communities. The modeling can thus discretely represent sanitary flow and I/I. Bacteria concentrations have been separately assigned to each flow component and tracked through the collection system model.
	Was it stated that there is not a significant groundwater infiltration	Base flow in regional streams typically varies from 1.5 cfs per square mile (cfsm) in spring to less than

MEG Session	MEG Comments	Responses
	contribution to the sewer system, or just that it will not be dynamically modeled? How leaky are the regional sewers?	0.5 cfsm in fall; regional sewers can be expected to exhibit similar variation in groundwater driven infiltration flows. For areas where such seasonality has not already been incorporated into the collection system models, monthly infiltration factors have been developed to represent this flow variation based on long-term flow data already collected by PVSC. We have compiled long-term flow data for the wastewater treatment plant and key permanent monitoring locations to establish seasonal infiltration factors.
Session 2 Mar 17, 2017	Whether New York City utilized a similar method for selecting their typical year?	The New York City analysis utilized the same methodology that was previously used to select the JFK 1988 typical year.
	Suggested that an official approval of the typical year report would be useful	The official approval of the typical year report was obtained from NJDEP on May 31, 2018.
	Whether Paterson Outfall 028 is included in the model as a CSO? NJDEP recently confirmed that it is a CSO.	Paterson Outfall 028 was added to the integrated model as an active outfall.
	Whether in-pipe sedimentation is being considered?	Sedimentation is not included in the baseline model. See response to Session 1 comment.
Session 3 Sep 15, 2017	How are rain gauges assigned to a subcatchment?	Rain gauges are assigned to a subcatchment based on Thissen Polygons.
	Standard time or Daylight Saving Time should be applied consistently to rainfall and flow monitoring data	Daylight Saving Time was used for both rainfall and flow metering data.

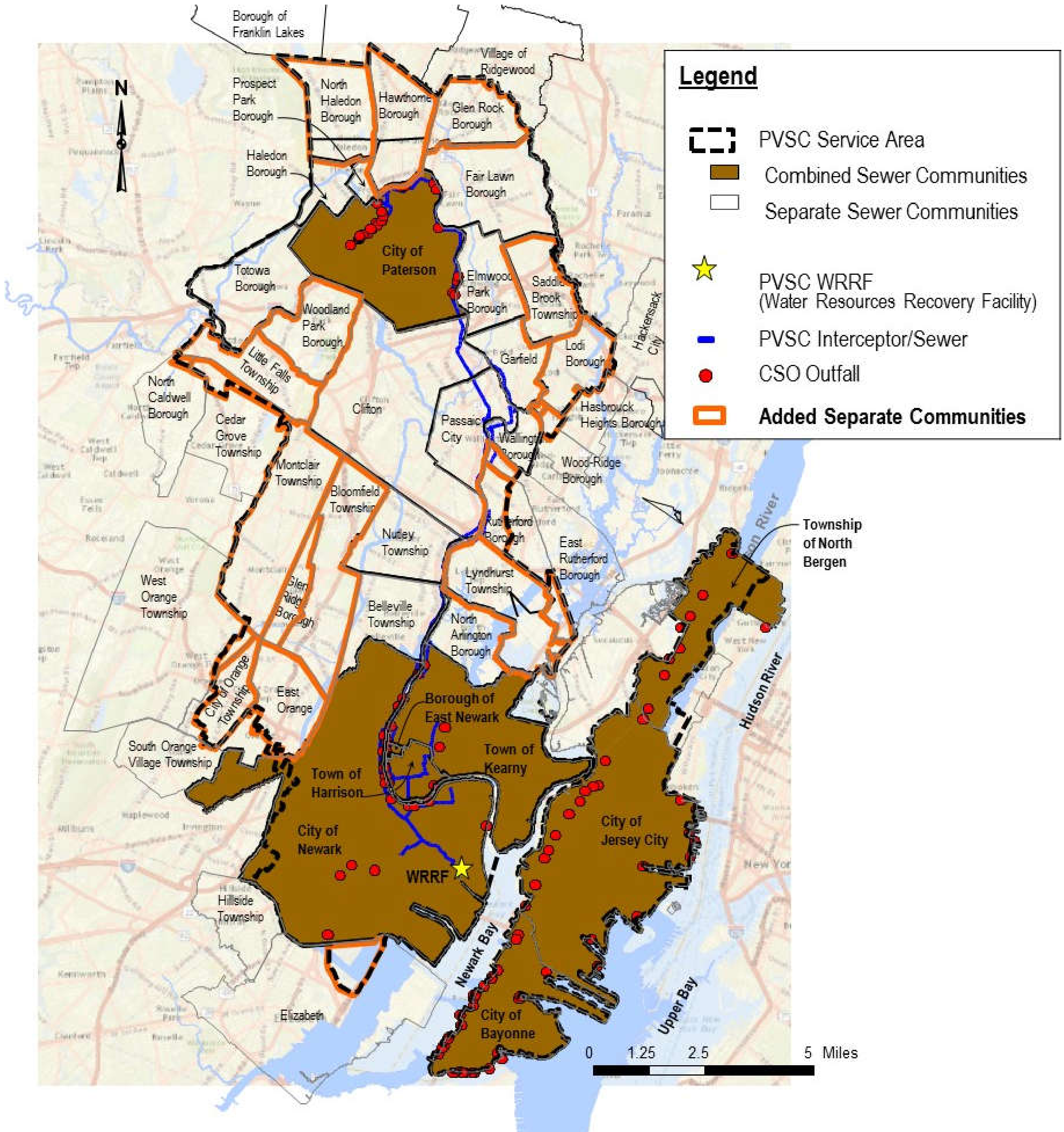


Figure I-18: Separate Communities Added during Model Expansion

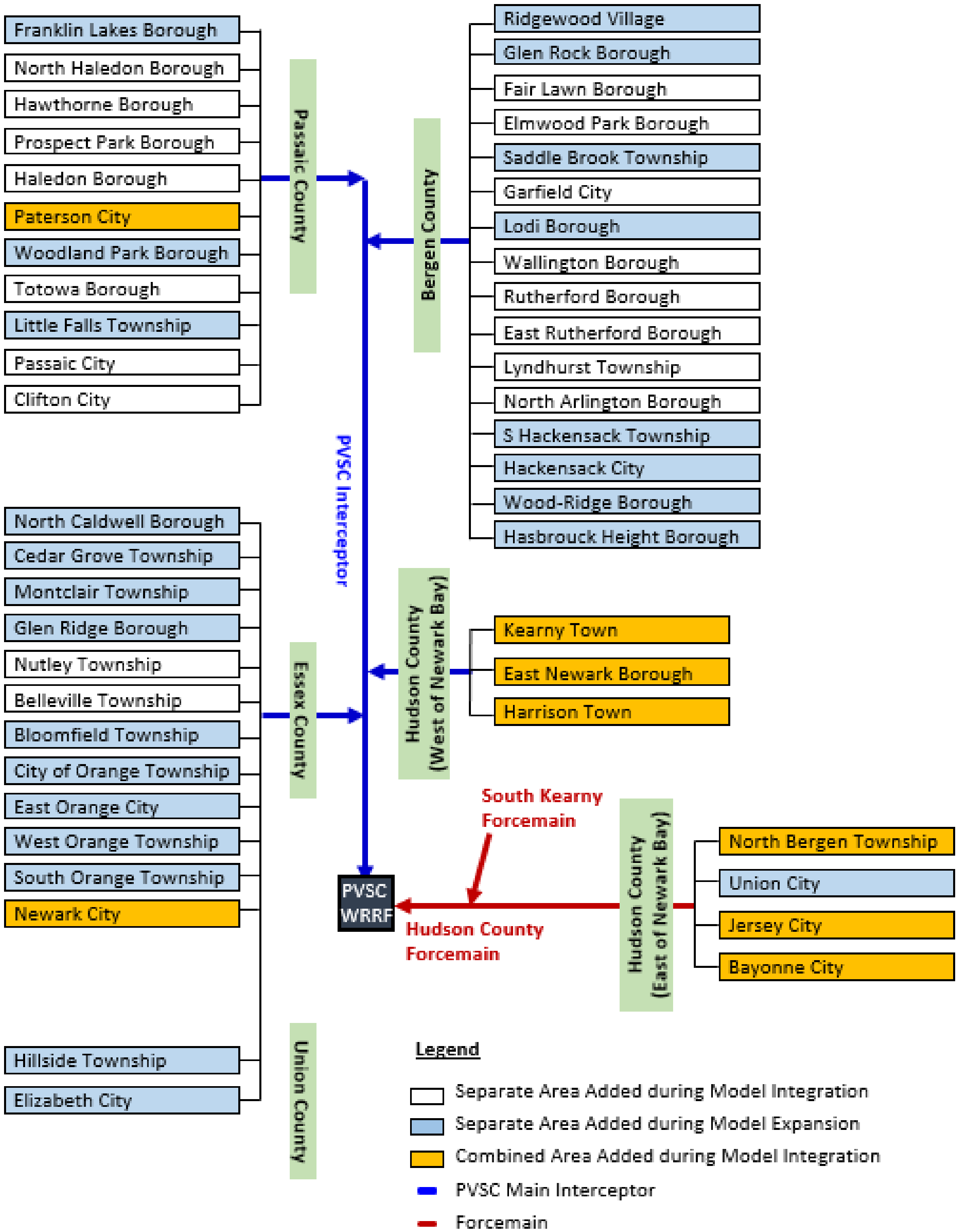


Figure I-19: Municipalities in the Final PVSC Model

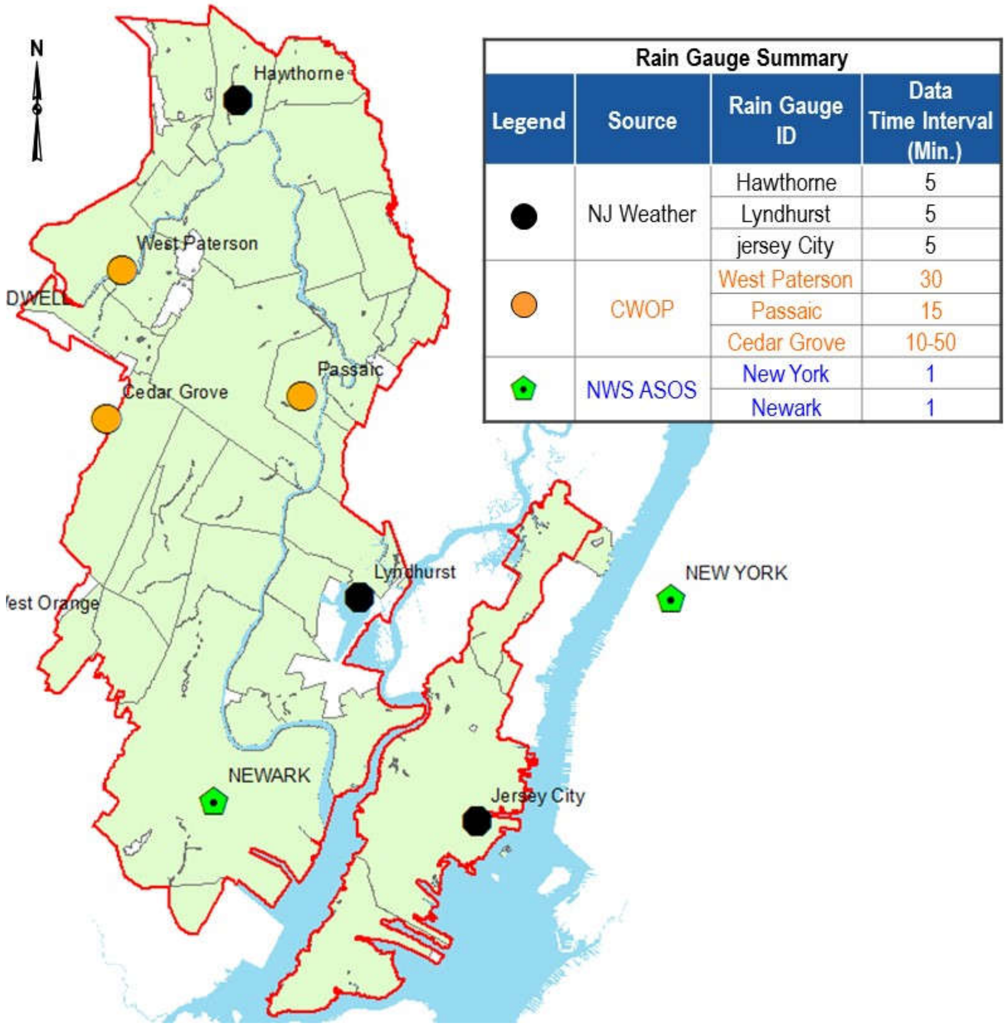
I.3 H&H MODEL COMPONENT AND INPUTS

I.3.1 Rainfall

Rainfall data assigned to a subcatchment within the model represent the average precipitation that falls on the area within a defined time interval. Rainfall data was entered in the model as rainfall intensity occurring within a time interval. The rainfall time interval can be as short as a minute or as long as an hour. Generally, the model results satisfactorily match observed flow monitor data when the rainfall input time interval is at a maximum of 15 minutes. Rainfall data recorded at 5-minute frequency were entered into the model for both model calibration and typical year simulation.

Model Calibration Rainfall: Rainfall records from eight (8) rainfall stations in the vicinity of the PVSC service area were used during model calibration to account for spatial rainfall pattern in the large area. **Figure I-20** shows locations of each rainfall stations in the map and summarizes data source and available time interval in the table. 5-min rainfall data was developed for model input based on the available time interval. Rainfall station was assigned to individual model subcatchment based on Thissen Polygons.

Typical Year Simulation Rainfall: Typical hydrologic period was analyzed based on rainfall records from the Newark station and Year 2004 was selected as the typical year (**Section H.2)**. 5-min rainfall data was developed based on the Newark NWS ASOS 1-min precipitation records for model input. This precipitation was applied to all subcatchments in the model for the typical year simulation.



Rain Gauge Summary

Legend	Source	Rain Gauge ID	Data Time Interval (Min.)
● (black)	NJ Weather	Hawthorne	5
		Lyndhurst	5
		jersey City	5
● (orange)	CWOP	West Paterson	30
		Passaic	15
		Cedar Grove	10-50
⬟ (green)	NWS ASOS	New York	1
		Newark	1

Figure I-20: Rainfall Stations Used in Model Calibration

I.3.2 Subcatchment

The model's surficial hydrology maintains the EPA SWMM runoff method used in the prior PVSC interceptor model and the Bayonne, North Bergen, and Guttenberg models that were incorporated into the comprehensive PVSC model. The SWMM methodology separately computes runoff from impervious and pervious surfaces based on a simplification of Manning's equation for shallow flow. Manning's equation computes discharge as:

$$Q = \frac{1.49}{n} A_w R_h^{2/3} S^{1/2}$$

where:
Q = discharge (ft^3/s)
n = Manning's roughness coefficient
A_w = wetted area (ft^2)
R_h = hydraulic radius (ft)
S = slope

The SWMM runoff method represents flow from a subcatchment as having A_w = dW, where d the depth of sheet flow and W is the representative width of sheet flow across the subcatchment orthogonal to the principal flow path. The hydraulic radius (wetted area divided by wetted perimeter) of this flow is dW/[W+2d]. As W is much larger than d (e.g. the width of runoff from a subcatchment is measured in feet, while sheet flow depth is typically a fraction of an inch), the hydraulic radius effectively equals d (e.g. for a sheet flow depth of 0.01 ft and width of 50 ft, R_h = 0.01 × 50 / [50 + 0.02] ≈ 0.01). Manning's equation can then be rewritten as:

$$Q = \frac{1.49}{n}(dW)d^{2/3}S^{1/2} \text{ or } Q = \frac{1.49}{n}Wd^{5/3}S^{1/2}$$

Instantaneous discharge from a subcatchment to its inlet is thus calculated from the depth of water over the subcatchment's "reservoir", Manning's "n", representative width, and subcatchment slope. This is known as the SWMM non-linear reservoir runoff model. W is the SWMM width parameter, identified in InfoWorks as the "dimension" parameter. It is usually calibrated during model development to control hydrograph shape: a large width increases instantaneous runoff and yields a sharp, rapidly-responsive hydrograph, whereas a small width yields a flatter hydrograph with a smaller peak and longer response. Manning's "n" and subcatchment slope are usually held constant during calibration, as adjusting these values has the same effect as adjusting W (the differing exponents mean that the response may be inverted or less pronounced, but the overall effect on the hydrograph is the same). The model is applied separately for impervious and pervious surfaces, and considers that initial abstraction (e.g. puddles) is applicable across most of a subcatchment, except on roofs and other steep surfaces.

Subcatchment Area

Figure I-21 shows the model's 732 subcatchments, 51 of which represent sanitary flows from contracted, lessee, and non-contracted contributing communities. **Table I-6** summarizes the number and size of subcatchments in each combined sewer community. Modeled contributing areas are generally smaller than total community area; some areas drain directly to receiving waters. Others, such as Newark Airport and the surrounding industrial area, are served by separate drain systems. As the model was assembled from various component models, the level of detail varies considerably among communities. Bayonne, which was previously represented in an independent model, has the most detail, with an average subcatchment size of 8 acres. Jersey City, which is only coarsely represented in this model, as it is currently being separately considered in another study, has the least detail, with just four subcatchments. The other combined communities have average subcatchment sizes ranging from 31 acres in East Newark to 250 acres in Kearny.

Table I-6: Subcatchment Summary

Municipality	Total Contributing Area (acres) [1]	Contributing area (acres)		Subcatchments	Average Acres per subcatchment
		Combined	Separate		
Bayonne	1,742	1706	36	229	8
East Newark	62	62	0	2	31
Guttenberg	124	111	13	5	25
Harrison	777	423	354	10	78
Jersey City	5,365	5,365	0	4	1,341
Kearny	4,006	1,243	2,763	16	250
Newark	10,036	7,153	2883	304	33
North Bergen	1,591	1,552	39	44	36
Paterson	5,195	4,595	600	67	77
40 Sanitary communities	55,214	0	55,214	51	1,083
Total	84,112	22,210	61,902	732	115

Note:

5. The total acreage in the table above includes only the subcatchment areas in the model that contribute flow to the PVSC WRRF. The acreage does not include rivers, creeks or unsewered areas within a municipality.

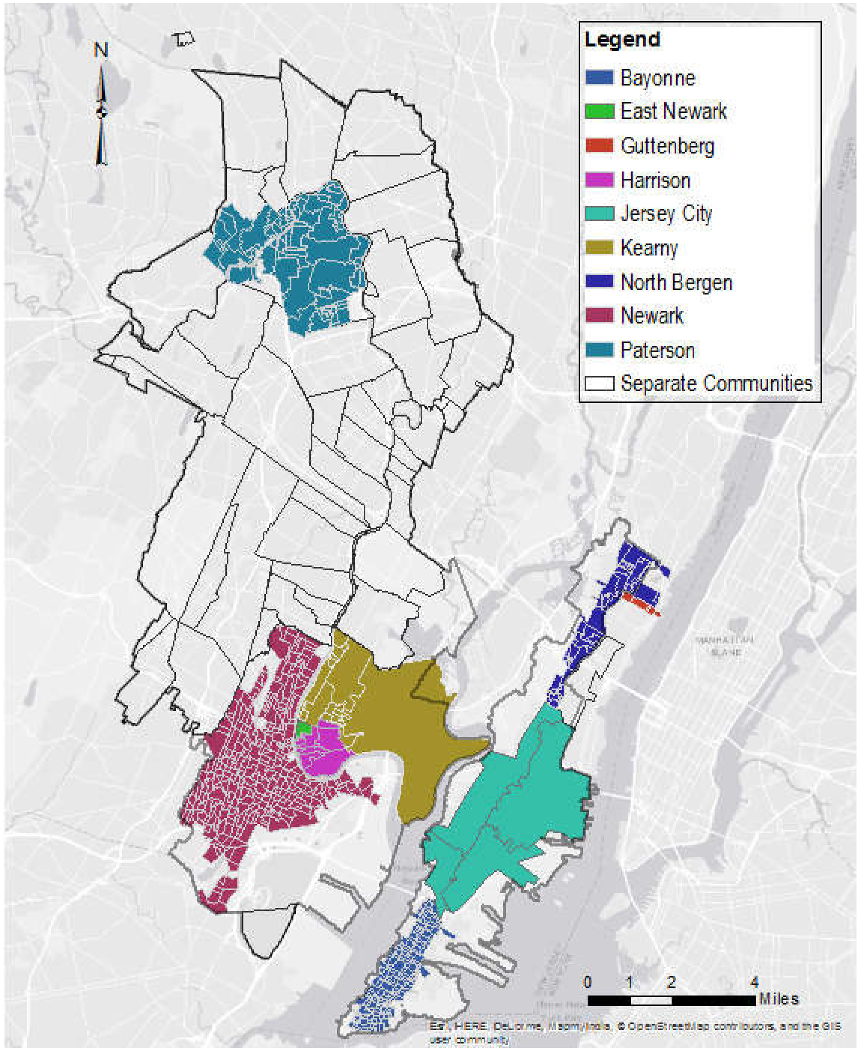


Figure I-21: The PVSC Service District

Subcatchment Percent Imperviousness

Effective imperviousness is the fraction of a subcatchment from which all rainfall runs off after initial abstraction for puddles and other minor depressions. It is calibrated in the combined sewer communities except Bayonne through adjustment of the "Runoff routed internally (%)" parameter. The Runoff routed internally parameter identifies the fraction of a catchment's total impervious surface (i.e. surfaces with negligible infiltration capacity) that drains onto adjacent pervious ground, such as roof leaders that drain to lawns. In Bayonne, no distinction was made between effective and total imperviousness in the model input data. **Table I-7** presents total and effective impervious area and percentages for each combined sewer community. Total imperviousness for all the combined sewer subcatchments computed from the *2011 National Land Cover Database (NLCD; Homer, C.G., et al., 2015)* is 70 percent, while effective imperviousness was calibrated as 41 percent. The disparity between these values suggests that the contributing area for the collection system is smaller than the modeled areas; while **Table I-7** shows that modeled areas are already smaller than the community extent, the true contributing areas appear to be smaller still. While the difference between total and effective impervious area suggests that modeled areas may be overestimated, the table indicates the comparative extent of effective impervious area among the communities: Newark and Jersey City together account for 65 percent of the impervious area across the combined service area, Bayonne and Paterson account for 21 percent, and the other communities account for 14 percent.

Table I-7: Impervious and Effective Impervious Area

Community	Modeled Area (ac)	Total Impervious Area (ac)	Effective Impervious Area (ac)	Total Imperviousness (%)	Effective Imperviousness (%)
Bayonne[1]	1,714	1,376	1,005	80	59
East Newark	62	52	31	84	50
Guttenberg	111	95	48	86	43
Harrison	427	342	145	80	34
Jersey City[2]	6,337	4,570	3,304	72	52
Kearny	1,243	782	390	63	31
Newark	7,167	4,942	2,839	69	40
North Bergen	1,555	1,093	641	70	41
Paterson	4,595	2,994	1,006	65	22
Total	23,210	16,246	9,409	70	41

1. Imperviousness and effective imperviousness not distinguished in model for Bayonne. Total impervious area reported from NLCD; effective imperviousness is as specified in model.
2. Jersey City is modeled coarsely in PVSC model. Jersey City has its own detailed model that was not used for this project.

Subcatchment Width

Subcatchment width is a principal calibration parameter, as hydrograph timing has many controlling factors such as catch basin density and conveyance characteristics of pipes omitted from the hydraulic model. For this study, widths in areas that had not been recently calibrated were initially specified based on a regression relationship for existing widths in the model, with width (feet) calculated as 300 $A^{0.6}$, where A is area in acres. For example, the median subcatchment area across all the combined sewer communities is 15 acres. The estimated width for a 15-acre subcatchment is 1500 feet, or 100 ft/ac. This can also be considered as an overland flow length of 430 feet, although the SWMM method does not explicitly account for overland flow. While unit width depends on various factors, higher values are generally associated with faster runoff and lower values with attenuated runoff. As shown in **Table I-8**, Bayonne has the highest unit width, and Guttenberg and North Bergen have the lowest unit widths.

Table I-8: Subcatchment Unit Width

Community	Unit Width (ft/ac)
Bayonne	123
East Newark	68
Guttenberg	9
Harrison	64
Jersey City	21
Kearny	31
Newark	90
North Bergen	9
Paterson	67
Total	42

Subcatchment Slope

Subcatchment slope was transferred from the component models into the systemwide model with only minor adjustments (except for the Jersey City values, which were directly estimated for this study). Average values by community are shown in **Table I-9**. Slope on its own is not of key importance, since, as discussed above, it is composited with width and Manning's "n" for computing runoff rates, and the width parameter was adjusted through calibration.

Table I-9: Average Slope %

Community	Slope (%)
Bayonne	1.0
East Newark	3.4
Guttenberg	0.5
Harrison	2.3
Jersey City	0.5
Kearny	3.5
Newark	2.1
North Bergen	4.2
Paterson	2.2
Total	1.8

Depression Storage

Except in Bayonne, impervious area was partitioned so that 75 percent of each subcatchment has an initial abstraction depth of 0.05 inches, and 25 percent of the area has no initial abstraction (representative of pitched roofs). In Bayonne, all impervious area is subject to 0.05 inches initial abstraction. Pervious areas across the entire model were specified with initial abstraction of 0.1 inches. During continuous simulation, available initial abstraction depth is restored based on evaporation.

Manning's "n" Roughness Coefficient

Overland flow travels slower or faster depending on the roughness of the surface in the subcatchment. The higher the roughness coefficient, the greater the friction and the slower the flow travels. Again, this is a model parameter that cannot be practically measured. A typical range of Manning's "n" suggested by the SWMM is 0.011-0.024 for impervious area and 0.05-0.80 for pervious area. The initial values were set to 0.02 for impervious surfaces and 0.05 for pervious surfaces. Roughness is an empirical value and may be treated as a calibration parameter if necessary.

Soil Infiltration

Pervious areas were uniformly modeled using the Horton infiltration equation with an initial infiltration rate of 5 inches per hour, and a limiting rate of 2 inches per hour. This typical infiltration rate was estimated from review of soils data for the area. Much of the area is identified in the national soils database as "urban land", for which no hydraulic properties are identified. The predominant named soil types are Boonton, Riverhead, Greenbelt, Whippany, and Parsippany, each of which has a saturated conductivity between 1 and 4 inches per hour. As few storms have sustained rainfall exceeding 2 inches per hour, runoff from pervious area is simulated for only a few hours a year. Most runoff in the combined service area comes from impervious surfaces. It is thus not possible to distinguish the impact of pervious area runoff from the available flow metering data. This is typical for CSO studies in areas with well-drained soils, such as those predominant in the PVSC combined service area.

I.3.3 Trunk sewer and Main Interceptor

Most of the gravity sewer mains and PVSC Interceptor in the final PVSC model were imported from the previous models during model integration. Sewer size, shape, invert, and Manning's "n" value were inherited from the previous models as well. A small amount of new sewer lines were added as needed during model expansion or refinement. Input for the new sewer lines were prepared based on available sewer GIS information or with appropriate assumptions (for example: assuming constant slope for neighboring sewers).

Manning's roughness coefficient is related to the pipe material. Manning's "n" values in the model are in the range of 0.009 to 0.049. Approximately 72% of the sewers have Maning's "n" of 0.015 in the model, 14% sewers have Manning's "n" of 0.010, and 10% with Manning's "n" around 0.013. The Manning's "n" may be changed during calibration to account for minor loss or additional sediment depositions in the pipe

I.3.4 Manhole

Most of the manholes in the final PVSC model were imported from the previous models during model integration. Manhole invert and rim were inherited from the previous models as well. A small number of new manholes were added as needed during model expansion or refinement. Input for the new sewer lines were prepared based on available sewer GIS information or with appropriate assumptions (for example: assuming constant slope for neighboring sewers, manhole rim at the ground contour, etc.).

I.3.5 CSO Outfall

All the permitted/active CSO outfalls were included in the model. More than half of the CSO outfalls have flap gates to prevent water backup from receiving water body. Outfall information in the final PVSC model were mostly imported from the previous models during model integration.

I.3.6 Regulator

CSO regulators and outfalls serve as combined sewer reliefs necessitated by stormwater entering the sewer system and exceeding the hydraulic capacity of the sewers and/or treatment plant. Wet weather flows in excess of the collection system's capacity are discharged to the receiving water body. There are 50 regulators included in the PVSC model. Regulator gate and weir dimensions and elevations were mostly inherited from the previous model during model integration. Regulator drawings received from PVSC were carefully reviewed to validate the settings in the model (**Table I-10**).

Table I-10: PVSC Regulators

Regulator #	Overflow Weir				Regulating Sluice Gate / Orifice					
	Drawing		PVSC Model		Drawing			PVSC Model		
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height
P_015A (S.U.M. Park)	152.9	2.5	152.9	2.5	151.87	1.25		151.87	1.25	
P-001A (Curtis Pl.)	146.9	3.83	146.9	3.83	143.94	3	1	143.94	2.25	
P-003A (West Broadway)	139.5	4	139.5	4	137.4	1.25		137.4	1.25	
P-005A (Bridge St.)	133.4	5	136.71	5	131.7	0.833	1.667	131.7	1.25	
P-006A (Montgomery St.)	134.2	8.0	135.25	8	129.53	2		129.53	2	
P-007A (Straight St.)	133.8	6	133.8	5	130.1	1.83	3	130.1	1.25	
P-010A (Keen St.)	135.4	4	135.4	4	133.44	1.67	0.83	133.44	1.25	
P-010A (Warren St.)	133.85	4	135.21	3						
P-016A (Northwest) modified	138.8	8	140.94	8.5	136.25	2.5		136.25	2.5	
P-017A (Arch St.)	135.7	4.5	135.69	3.67	132.6	1		132.6	1	
P-032A (Hudson St.)	135.2	4	135.2	4						
P-022A (Short St.)	132.6	4.5	132.6	4.5	130.63	2		130.63	2	
P-021A (Bergen St.)	132.7	4.5	132.7	4.5	130.75	1		130.75	1	
P-013A (E. Eleventh St.)	133.4	4.83	133.4	4.83	131.7	1.67	0.83	131.7	1.25	
P-014A (Fourth Ave.)	140.9	4.5	140.9	3	137.76	1.67	0.83	137.76	1.25	
P-023A (Second Ave.)	129.8	4.5	130.56	5	127.4	Not available		127.4	1.25	
P-024A (Third Ave.)	130.3	4.5	130.3	5	128.2	1.67	0.83	128.2	1.25	
P-025A (East 33rd Ave.)	128.9	8.58	129.87	8.58	127.07	3	1	127.07	2	
P-026A (East 20th Ave.)	129.2	5.5	128.92	5.5	126.95	1.67	0.83	126.95	1.66	0.83
P-027A (Market St.)	131.1	7.11	131.1	4.0	129.6	3.5	1.167	129.6	3.5	2.0
					129.6	3.5	1.167	129.6	3.5	0.0

Regulator #	Overflow Weir				Regulating Sluice Gate / Orifice					
	Drawing		PVSC Model		Drawing			PVSC Model		
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height
N-002A (Verona Ave.) modified	110.43	41	103	6	102.65	2.5	2.5	99.33	2	2
N-004A/005A (Herbert) modified	114.34	41	105.55	6.667	107.06	2	2	103.6	1.5	1.5
N-008A (Fourth Ave.)	103.5	6	103.5	6	100.7	1.5	1.5	100.7	1.5	1.5
N-009A (Clay St.)	103.24	4	103.24	4	102.4	1.66	0.83	102.4	1.66	0.83
N-010A (Clay St.)	105.12	8.42	105.12	8.42	101.24	6	3	101.24	6	3
	105.12	8.42	105.12	8.42	101.24	6	3	101.24	6	3
	105.12	8.42	105.12	8.42						
N-014A (Rector) modified	102.56	5.5	103.66	5.5	99.97	1.5	1.5	101.07	1.5	1.5
N-014A (Saybrook) modified	102.33	7	103.43	7	99.02	2	2	100.12	2	2
N-015A (City Dock) modified	98.67	14	98.67	14	95.67	3.5	2.5	95.67	3.5	2.5
N-016A (Jackson St.)	97.62	7	97.62	4.5	96	1.5	1.5	96	1.33	1.33
N-017A (Polk St.)	97.8	8	97.8	7	95.2	1.5	1.5	95.35	1.33	1.33
N-018A (Freeman St.)	100.26	4	100.26	4	99	2	2	99	2	2
N-022A (Roanoke Ave.)	98.93	6	98.93	6						
N-027A/029A (Waverly)	102	4.5	102	4.5	96.4	4	2.33	96.4	4	2.33
N-025A (Peddie St.)	98.6+	6	98.6	8	93	4	2.33	93	4	2.33
	98.6+	8	98.6	8						
	105.85	5	98.6	8						
	105.85	5	98.6	8						
N-030A (Ave. A)	102.32	10	102.32	10	99.04	4	3	99.04	4	3
N-023A (Adams St.)	98.54	7	98.54	7						
K-001A (Stewart Ave.)	120.85	4.5	120.27	1.5	119.07	1		119	1	
K-004A (Nairne Ave.)	107.9	1.5	108	1.5	106.9	1		107	1	
K-006A (Johnston Ave.)	99.9	5	100.9	10	98.7	1.5		98.2	1.5	
	100.1	5								
K-007A (Ivy St.)	103	9	103	9	100.2	3	1	100.2	3	1
K-010A (Duke St.)	102.5	4	102.5	4.5	98.84	1	1	100.45	1	
E-001A (Central Ave.)	101.6	4	101.6	4	99.2	1.25		99.2	1.25	
H-001A (Hamilton Ave.)	101.2	4	101.2	4	99.8	1.25		99.8	1	
H-002A (Cleveland Ave.)	102.2	4	102.2	4	101	1		101.2	1	
H-003A (Harrison Ave.)	103.9	4	103.9	4	101.4	1.25		101.4	1.25	
H-005A (Middlesex St.)	100.8	3.5	100.8	3.5	99.1	1		99.1	1	

Regulator #	Overflow Weir				Regulating Sluice Gate / Orifice					
	Drawing		PVSC Model		Drawing			PVSC Model		
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height
H-006A (Bergen St.)	99.9	4	99.9	4	97.9	1		97.9	1	
H-007A (Worthington Ave)	102.4	4.5	102.4	4.5	101.2	1		101.2	1	

* Red font color was applied when the dimensions were different between the Drawings and the PVSC Model. The PVSC Model inputs were maintained.

I.3.7 Pump Station and Force Main

Hudson County Force Main were added in the model based on record drawings. It conveys flows from the municipalities located east of Newark Bay (including North Bergen, Union City, Jersey City and Bayonne) to the PVSC wastewater treatment plant.

In addition to the pump stations inherited from the previous model, South Kearny Pump Station and force main were added to the model to convey flows from the Kearny Meadowlands District and South Kearny District. Both districts are served with separate sewers. The service area of the pump station is shown in **Figure I-22.** Maximum capacity of the pump station is 17.5 MGD, with dry weather flows around 1.6 MGD.

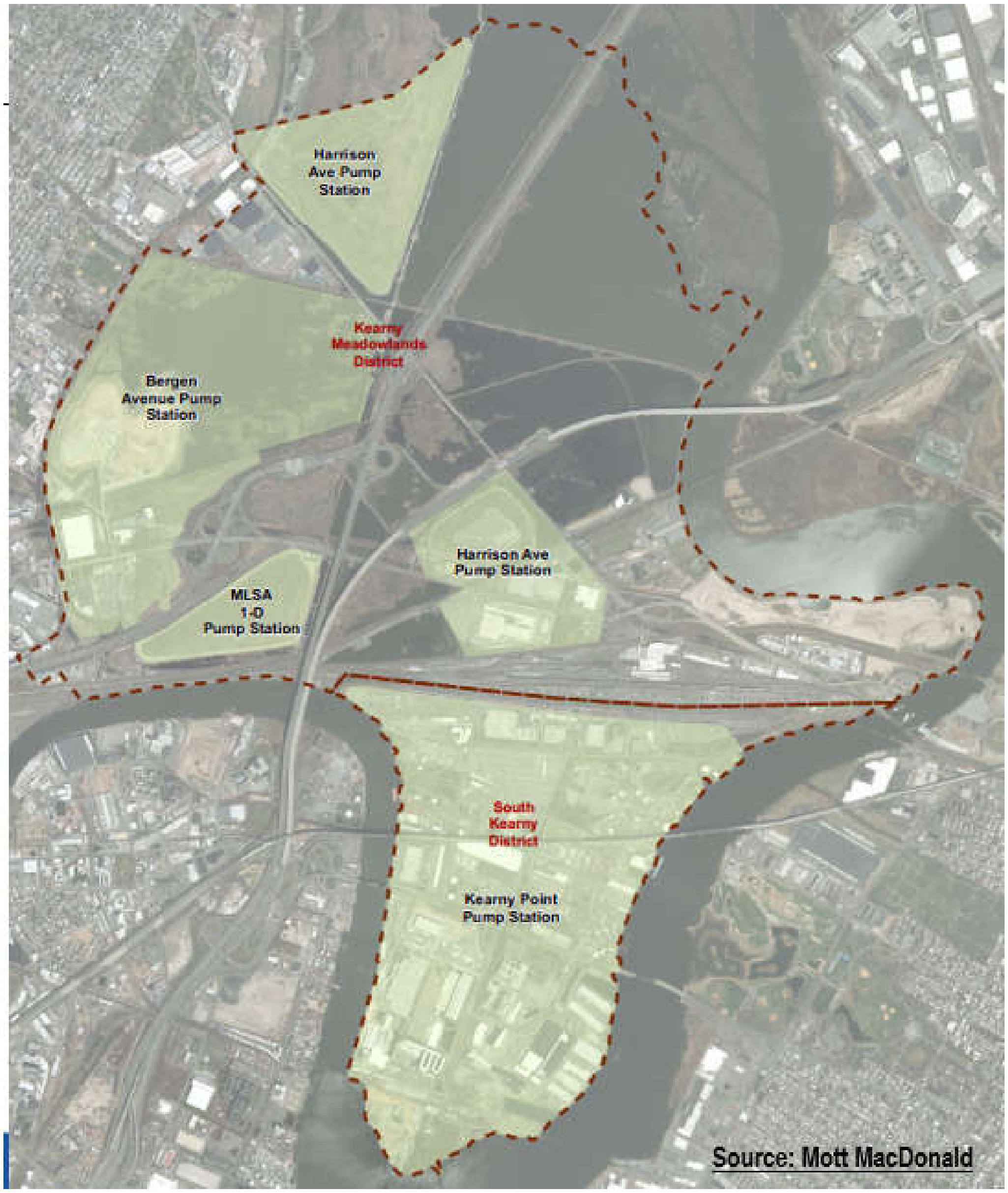


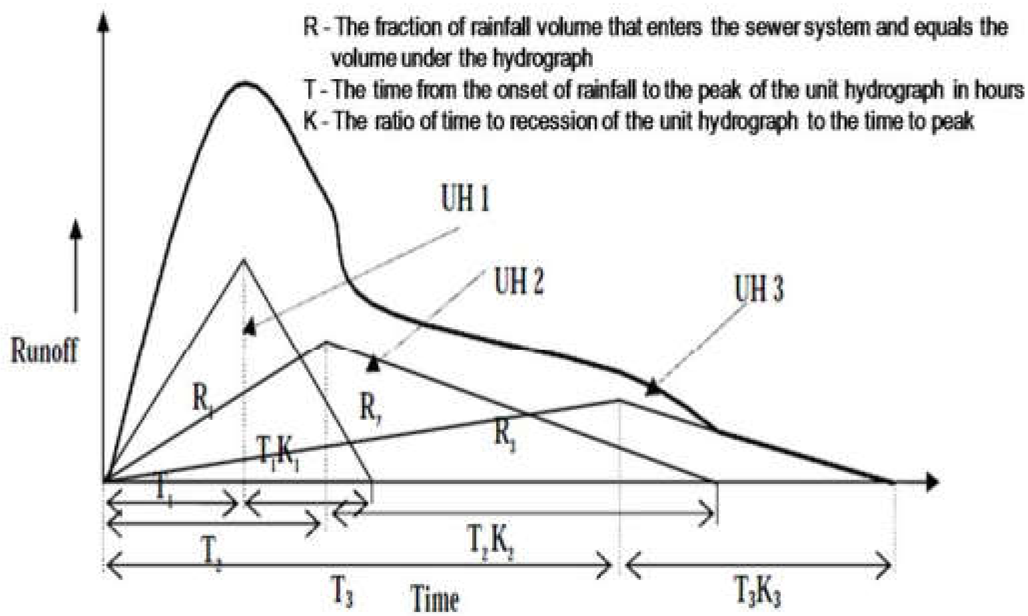
Figure I-22: South Kearny Pump Station Service Area

I.3.8 Rainfall Derived Infiltration and Inflow (RDII)

The model uses the RTK unit hydrograph (UH) to estimate RDII into the separate area sewer systems. As shown in **Figure I-23**, a RTK UH set contains up to three hydrographs (Muleta & Boulos, 2008): one for a short-term response (UH1), one for an intermediate-term response (UH2), and one for a long-term response (UH3). UH1 represents the most rapidly responding inflow component and has a short T value, UH2 includes both inflow and infiltration and has a longer T value, and UH3 includes infiltration that may continue long after the storm event has ended and has the longest T value. The unit hydrograph is defined by the following three parameters:

- R: the fraction of rainfall volume that enters the sewer system and equals to the volume under the hydrograph,
- T: the time from the onset of rainfall event to the peak of the unit hydrograph in hours, and
- K: the ratio of time to recession of the unit hydrograph to the time to peak.

The same set of RDII parameters were applied in the same metershed because of the availability of the flow hydrograph for model calibration. The initial values of RTK were estimated based on previous modeling document. The RTK values are calibration parameters to be refined during model calibration.



Source: M.K. Muleta and P.F. Boulos, Analysis and Calibration of RDII and Design of Sewer Collection Systems, ASCE Conference Proceedings 316, 642 (2008)

Figure I-23: RTK Unit Hydrograph

I.3.9 Dry Weather Flow

Dry Weather flow shown in **Figure E-3** was assigned to subcatchments in proportion to the service area in the same metershed. Same weekday and weekend dry weather flow diurnal patterns (example **Figure E-4**) developed from flow metering data were assigned to the subcatchments in the same metershed. Concentration of Pollutant PL1 was assumed to be 100 for all dry weather input, this allows users to differentiate wet weather flow quantity from the dry weather flow quantity.

I.3.10 Real Time Control (RTC)

RTC for Gate Operation of Regulators along PVSC Interceptor

Real time controls for gate operation of regulators along PVSC interceptor were developed based on the PVSC Primary Clarifier Auto Fill System Operating Procedure (SOP, October 27, 2016). The SOP includes sequenced procedures to be performed during wet weather conditions. These procedures were incorporated into the PVSC model through real time controls. Schematics in **Figure I-24** illustrate the following wet weather operating procedures in the model:

(a) When the WRRF flow (including flows from the Hudson County Force Main) is less than 350 MGD, all regulator gates are kept open

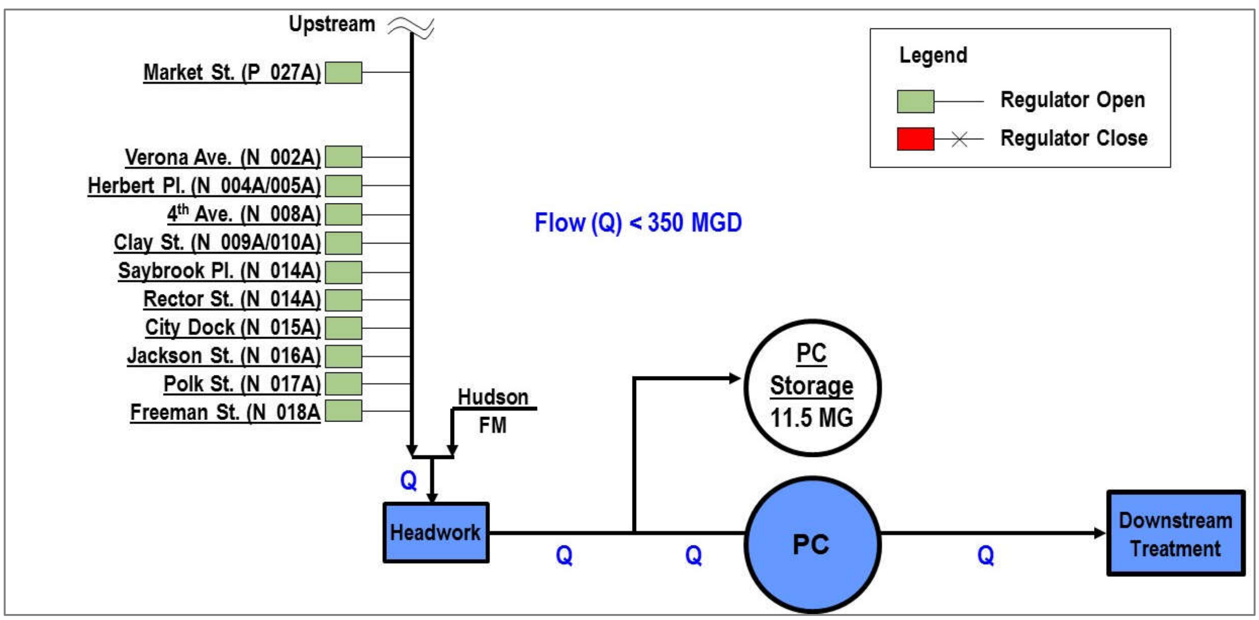
(b) When the WRRF flow increases above 350 MGD, close regulator gates on Verona Ave. (N_002A), Herbert Pl. (N_004A/005A), 4th Ave. (N_008A), Saybrook Pl. (N_014A), City Dock (N_015A), Jackson St. (N_016A), Polk St. (N_017A), and Freeman St. (N_018A).

During 10/7/2015 to 7/7/2016 (model calibration events were in this period), these regulator gate were put in use at plant flow 400 MGD.

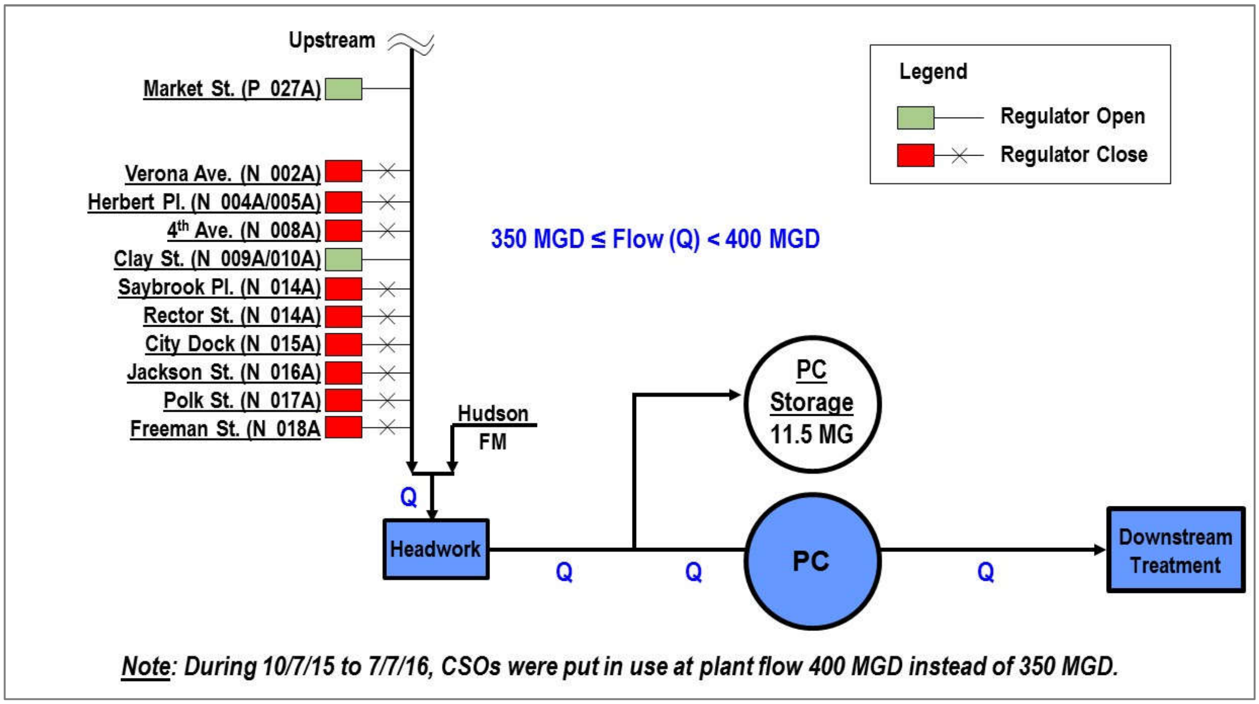
(c) When the WRRF flow further increases to above 400 MGD, start primary clarifier (PC) filling at flow rate 50 MGD

(d) When the PC storage is full, stop PC filling and close regulator gate at Clay St.

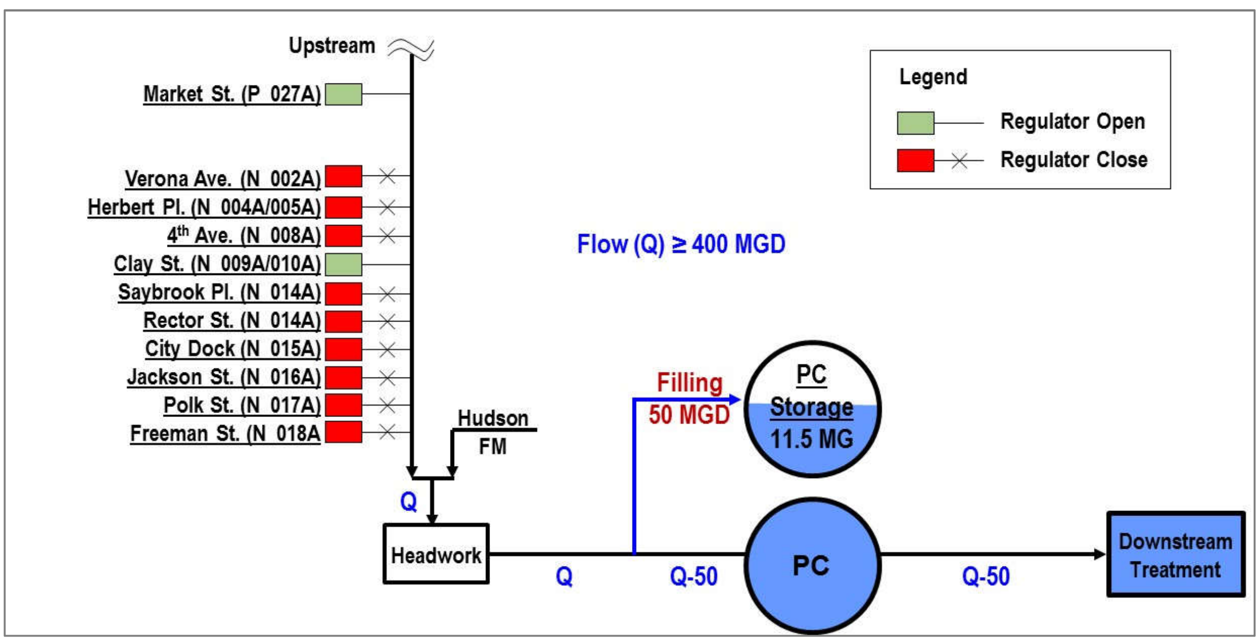
(e) When the WRRF flow recede to 350 MGD post storm event, open all regulator gates and start dewatering PC storage



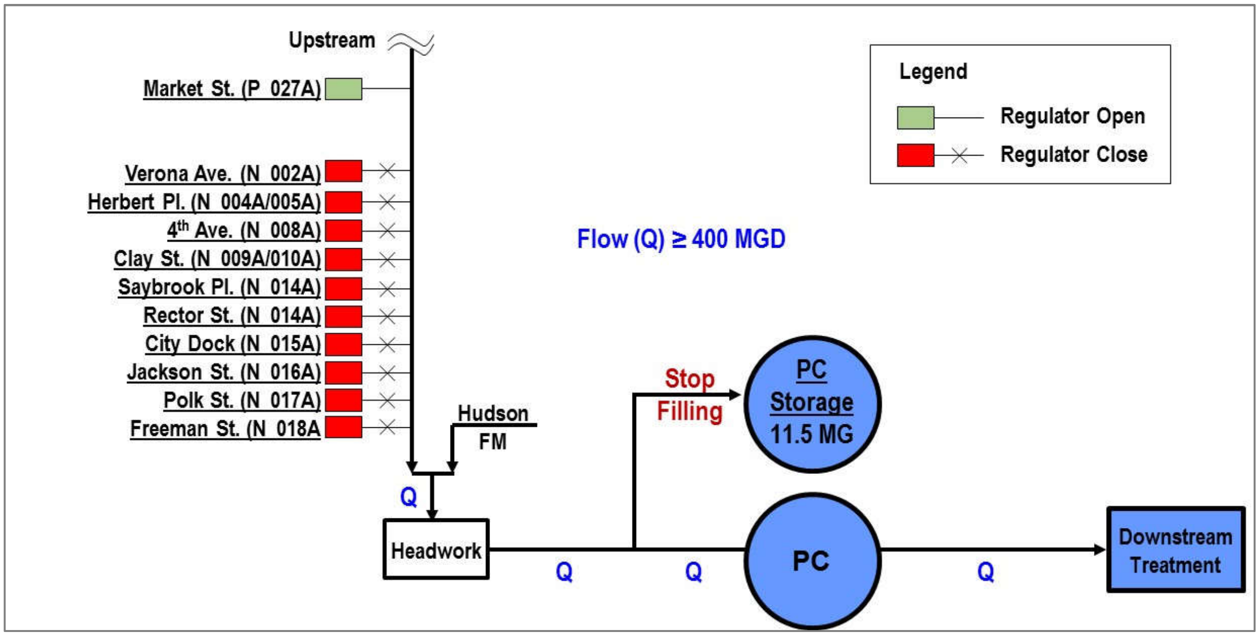
(a) Keep regulator gate open when WRRF flow is less than 400 MGD



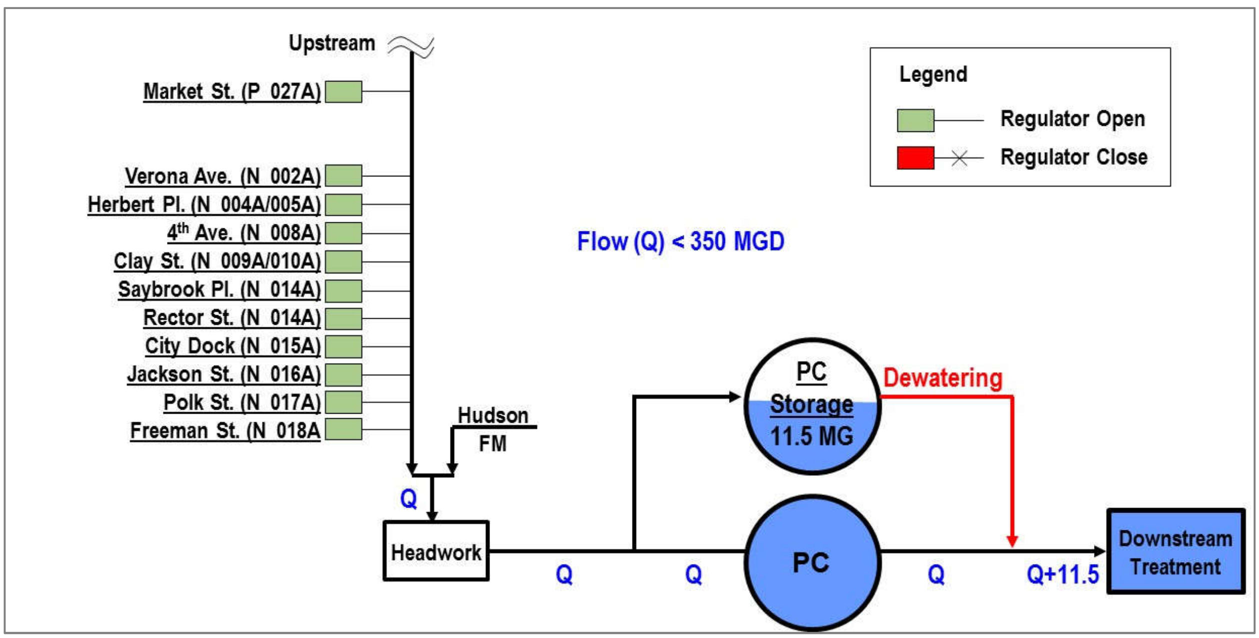
(b) Close regulator gates (except Clay Street) when WRRF flow is greater than 350 MGD



(c) Start filling PC Storage when flow is greater than 400 MGD



(d) Close Clay Street regulator gate when the PC Storage is full



(e) Open regulator gate and dewater PS Storage when WRRF flow recedes to 350 MGD

Figure I-24: PVSC Wet Weather Operating Procedure

RTC for Gate Operation of Regulators in City of Bayonne
All real time controls for City Bayonne regulators are inherited from its original model, with update of unit conversion detailed in **Table I-4.**

I.4 SUMMARY

The PVSC CSO LTCP model was developed from the integration of four existing CSO community models in InfoWorks ICM 7.5 based on PVSC datum. The model was then further expanded to include all separate sewer service area. The model has the following feature:

- 732 subcatchments, including all 48 served communities (both combined and separate)
- 2735 nodes, including 2621 manholes, 103 CSO outfalls, and 11 storage for pump station wet well and primary clarifiers served as storage facility. Real time control rules were set up for filling the primary clarifiers served as storage facility based on the wet weather Standard Operating Procedure (SOP) of PVSC WRRF.
- 2873 links, including 2567 conduits, 33 orifice, 103 weirs, 82 flap valves, 74 sluice gates, and 14 pumps. Thirty of the 74 gates are with variable gate openings to be regulated during wet weather conditions. Real time control rules were set up for the variable gate based on wet weather SOP.
- Hudson County Force Main was extended to the PVSC WRRF based on drawings to convey flows from the Hudson County to the WRRF. Force main from Bayonne was extended to the tie-in point to the Hudson County Force Main. Force Main from North Bergen was extended to the Jersey City sewer system.
- South Kearny pump station and force main are also added and tied into the Hudson County Force Main. The force main receive flows from Kearny Meadowlands District and South Kearny District, both areas are with separate sewer.
- Dry weather flow based on 2016 flow monitoring data.
- Wet weather flow simulated as runoff from the combined areas and RDII from the separate areas.
- Real time control based on the current PVSC WRRF wet weather SOP.

I.5 H&H MODEL CALIBRATION

Model credibility is developed through model calibration and validation. Model calibration involves application of the model to known external inputs (e.g., rainfall), evaluation of the model's ability to replicate monitored conditions (e.g., flow and volume), and adjustment of key model parameters as needed until an acceptable level of agreement is reached between simulated and monitored conditions.

The collection system H&H Model was calibrated in conjunction with the flow monitoring. The H & H Model was calibrated by running the model with rainfall data collected from selected storms and then comparing the calculated results to the actual flow monitoring data collected. The model parameters were adjusted and the process repeated until the calculated results approximated the actual flow monitor measurements. Goals for the model calibration included:

- To match visually the shape of the curve between model and flow monitor.
- To match model runoff volumes (volume under curve) to actual runoff volumes.
- To match model runoff peak flow rates to actual runoff peak flow rates.

I.5.1 Dry Weather Flow Calibration

Dry weather flow (DWF) analysis was based on the rainfall and flow monitoring results. DWF distribution in the collection system was based on land use data. Weekday, weekend and monthly diurnal factors from the DWF analysis were applied for each flow meter service area. Upstream meters in the system were calibrated first, then flows through the system to the pumps stations and to the WRRF were balanced. **Figure E-3** shows the arrangement of the meters in the system and meter identification.

The DWF calibration goals are:

- The simulated hydrograph should match the general observed hydrograph shape,
- The simulated time of peaks and troughs will be within 1 hour of the observed,
- The simulated peak flow will be within 10% of the observed flow, and
- The simulated flow volume over 24 hours will be within 10% of observed flow.

After the dry weather calibration was considered to be satisfactory, the model was calibrated for wet weather periods as described below.

I.5.2 Wet Weather Calibration

Wet weather flow (WWF) includes surface runoff from the combined area and RDII from the combined and separate sewered areas. Surface runoff parameters for the combined area and RDII parameters for the separate area were adjusted to calibrate the system response to the wet weather conditions.

Four (4) wet weather events were selected for wet weather calibration. Final selections include wet weather events with various rainfall intensities and volume.

The WWF calibration goals were:

- The simulated hydrograph should match the general observed hydrograph shape,
- The simulated time of peaks and troughs will be similar,
- The simulated peak flow for significant peaks will be within the range of -15% to +25%,
- The simulated flow volume will be within the range of -20% to +20%,

Storm events were analyzed based on precipitation data from the Newark Liberty International Airport. Four storm events selected for calibration of the collection system model met all the desired storm characteristics as describe in **Section E** of this Report. The July 25, 2016 storm was a 1.81-inch storm with a duration of approximately 3 hours and a maximum intensity of 1.68 in/hr. The May 29, 2016 storm was a 1.60-inch storm with a duration of 5.5 hours and a maximum intensity of 1.09 inches/hour. The July 29, 2016 storm was a 0.85 inch storm with a duration of 8.25 hours and a maximum intensity of 0.42 in/hr. The July 31, 2016 rain event was a 0.69-inch storm with a duration on 14 hours and a maximum intensity of 0.49 in/hr. Data on these storms is shown in **Table I-11**.

Table I-11: Wet Weather Events for Model Calibration and Validation

Event Start	Event End	Duration (hr)	Depth (in)	Max Intensity (in/hr)	Average Intensity (in/hr)
7/25/16 16:05	7/25/16 18:50	2.75	1.81	1.68	0.66
5/29/16 23:50	5/30/16 5:20	5.50	1.60	1.09	0.29
7/29/16 0:20	7/29/16 8:35	8.25	0.85	0.42	0.10
7/31/16 8:35	7/31/16 22:35	14.00	0.69	0.49	0.05

Examples of model calibration results are shown in the following figures for the observed and simulated flow, the one-to-one plots for modeled versus observed volumes, and the one-to-one plots for modeled versus observed peak flows. A well calibrated model will result in plotted values that are close to a one-to-one relationship. Deviations from this one-to-one relationship can be result from a variety of factors including error inherent with monitoring data, special variations in rainfall, and model limitations. When a modeled versus observed point is well outside of the calibration goal range, a note is provided to explain the likely cause of the discrepancy.

- **Figure I-25** to **Figure I-28** for flow meters in along the PVSC Interceptor;
- **Figure I-29** to **Figure I-32** for flow meters in the separate sewer area,
- **Figure I-33** to **Figure I-36** for flow meters in the combined sewer area, and
- **Figure I-37** to **Figure I-38** for flow meters in the CSO overflow lines.

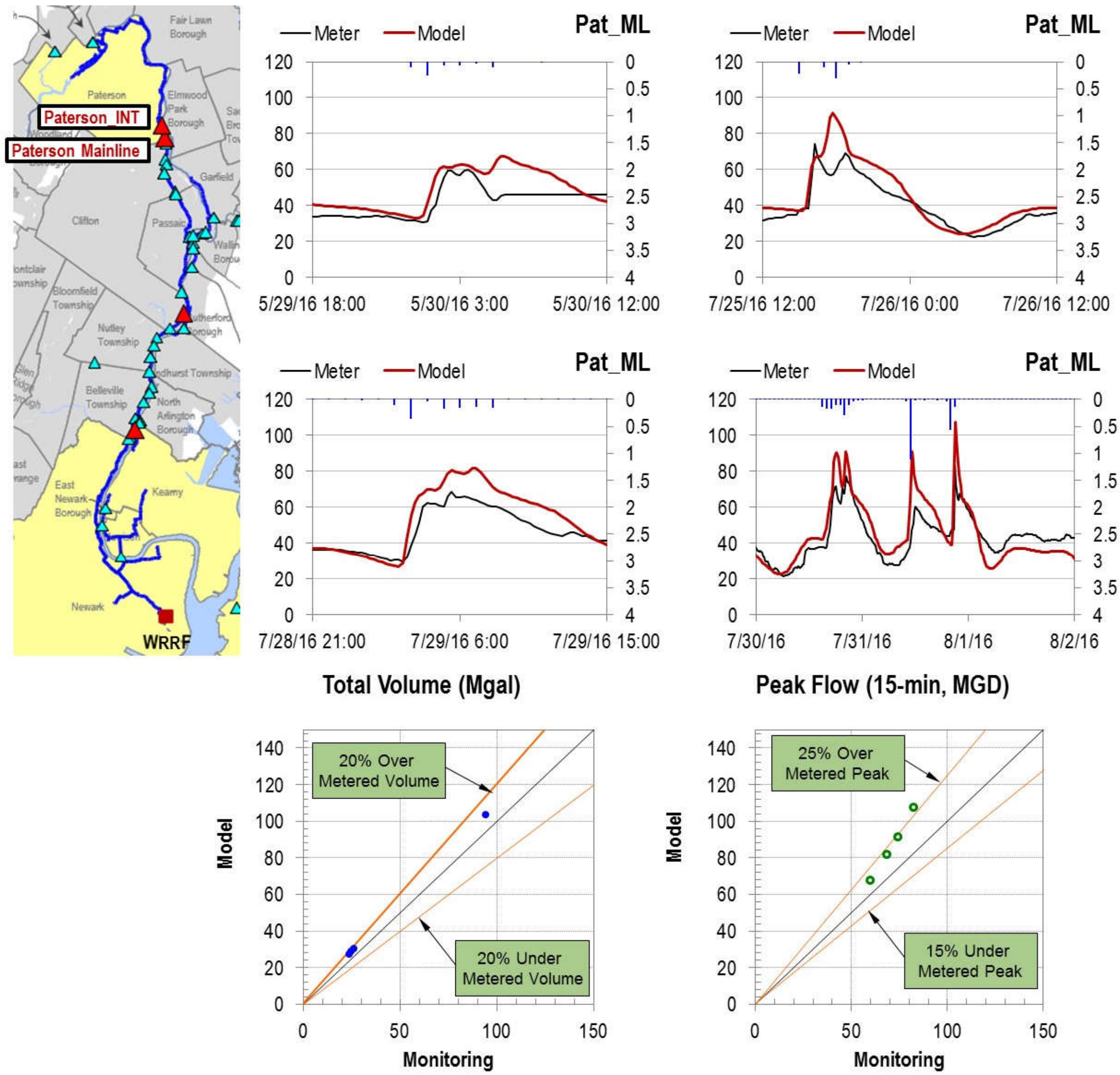


Figure I-25: Calibration Plot for Interceptor_Paterson Main Line

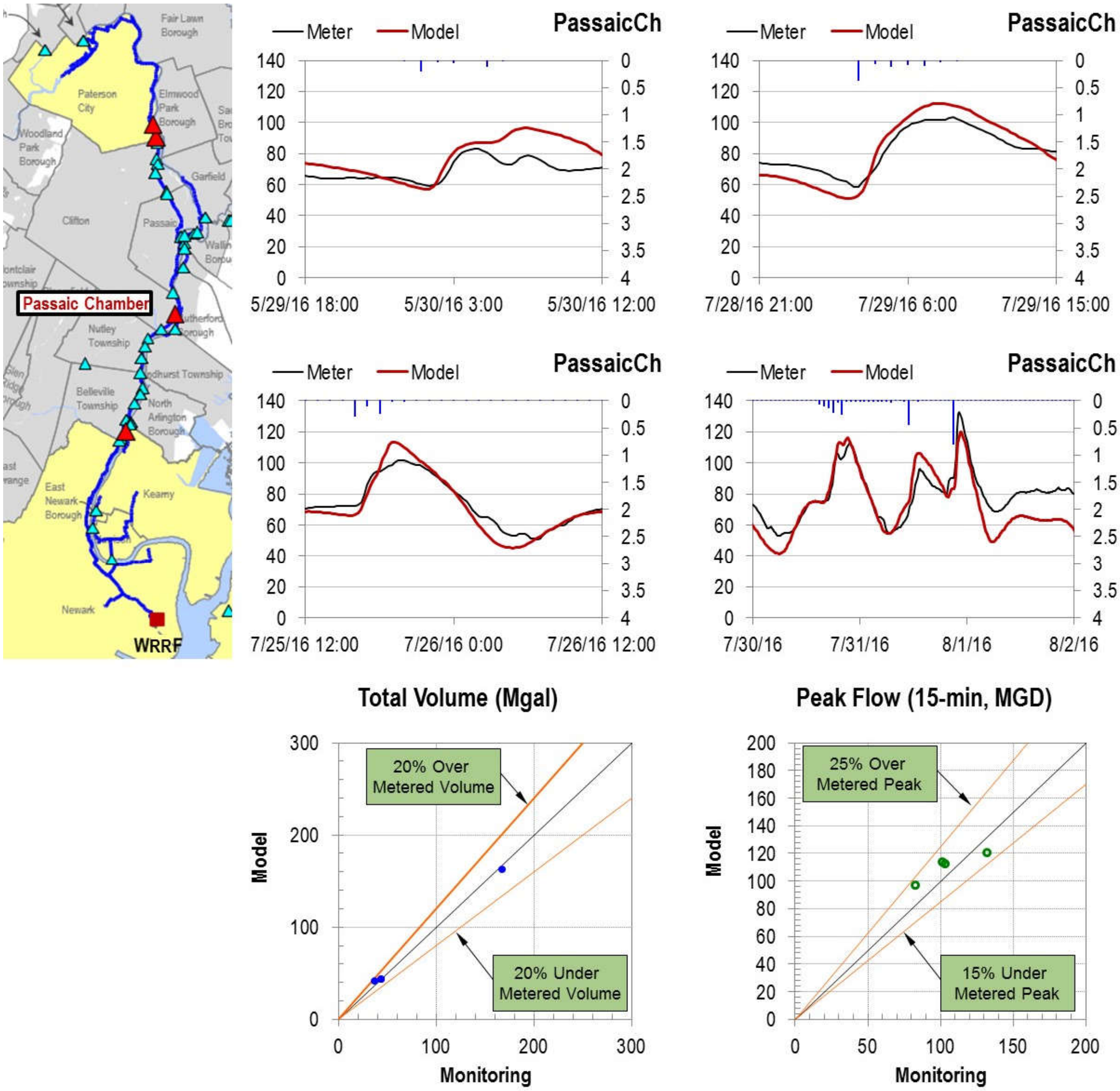


Figure I-26: Calibration Plot for Interceptor_Passaic Chamber

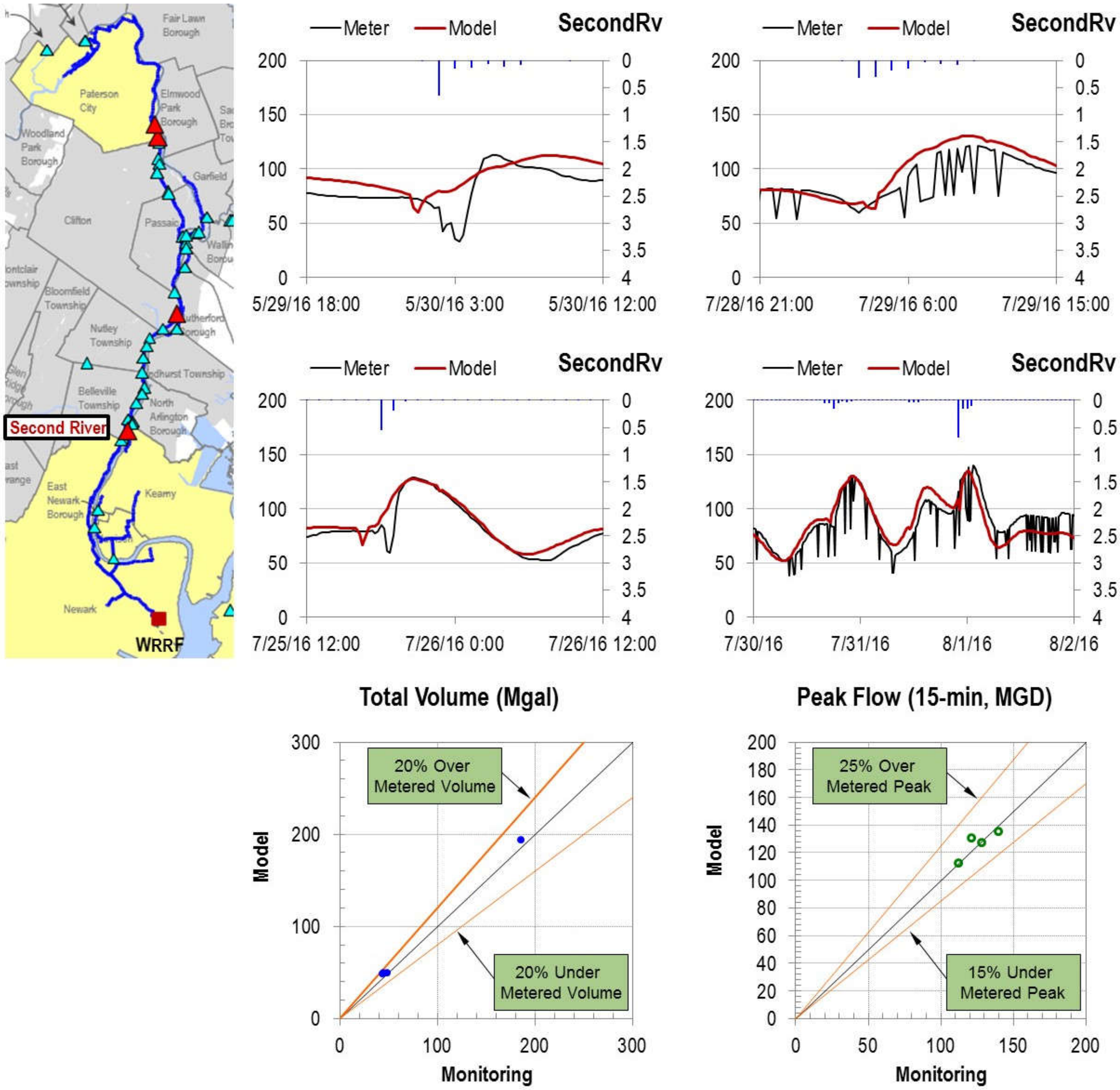


Figure I-27: Calibration Plot for Interceptor_Second River Crossing

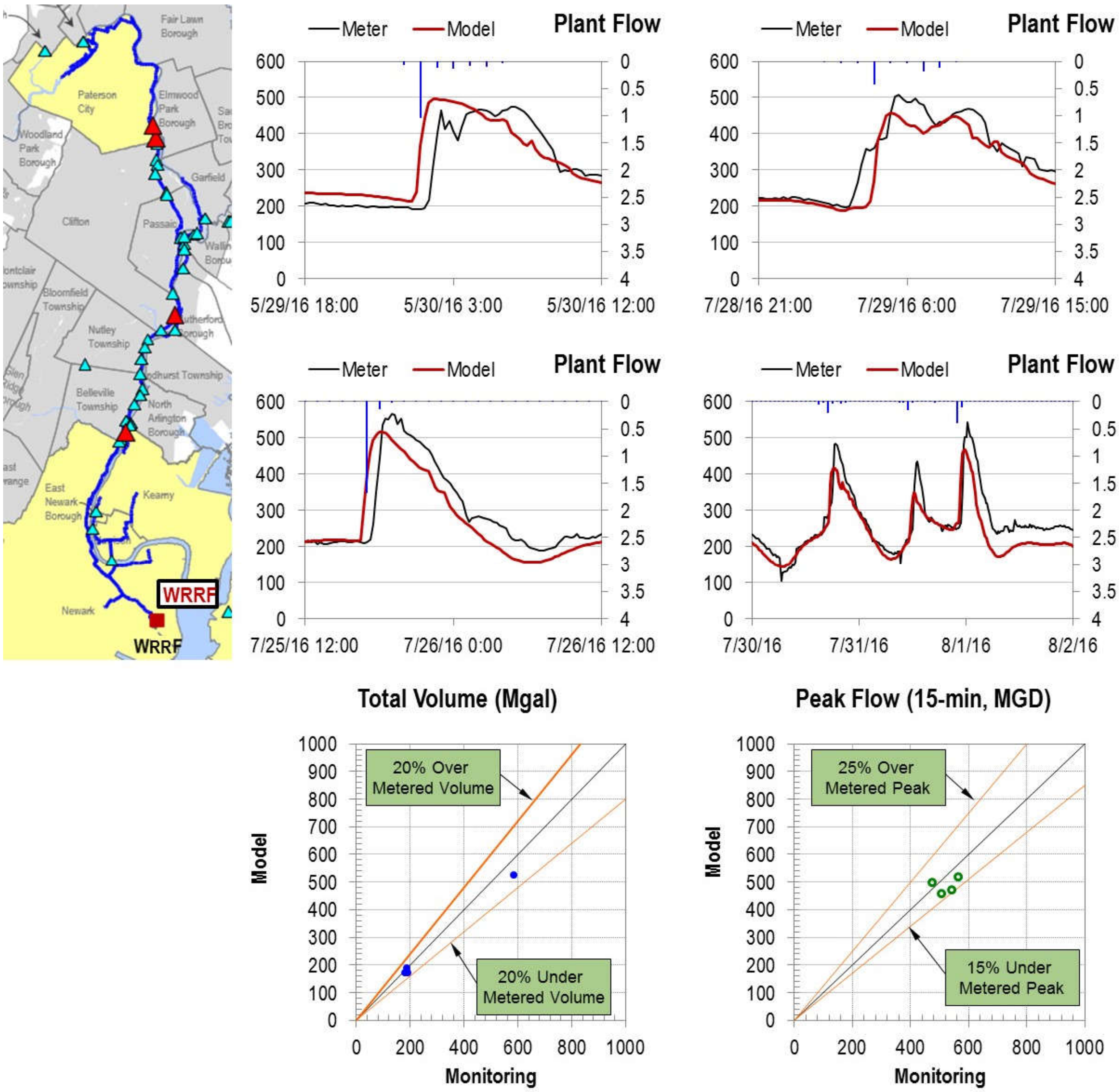


Figure I-28: Calibration Plot for PVSC Interceptor_WRRF

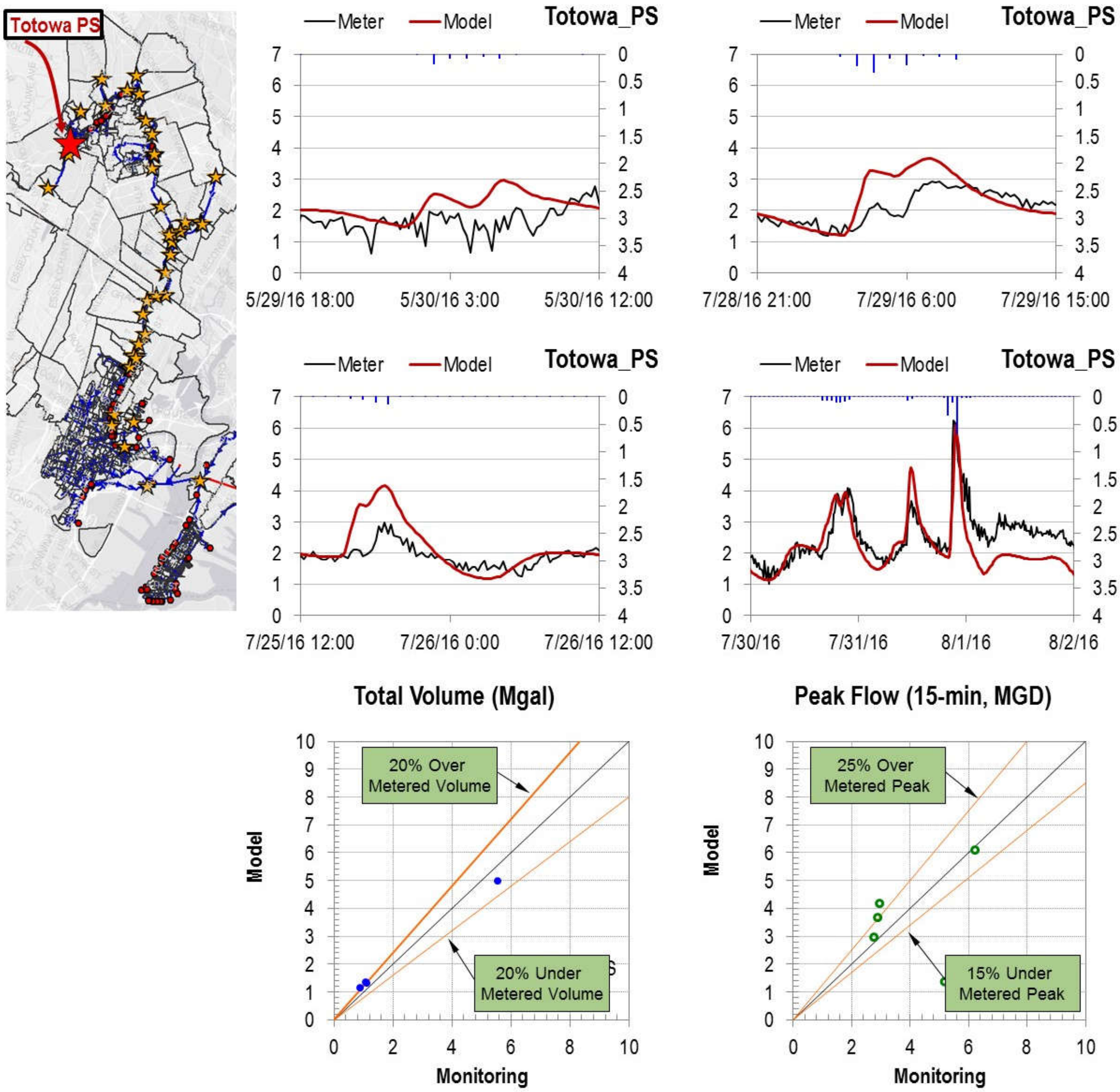


Figure I-29: Calibration Plot for Separate Area_Totowa PS

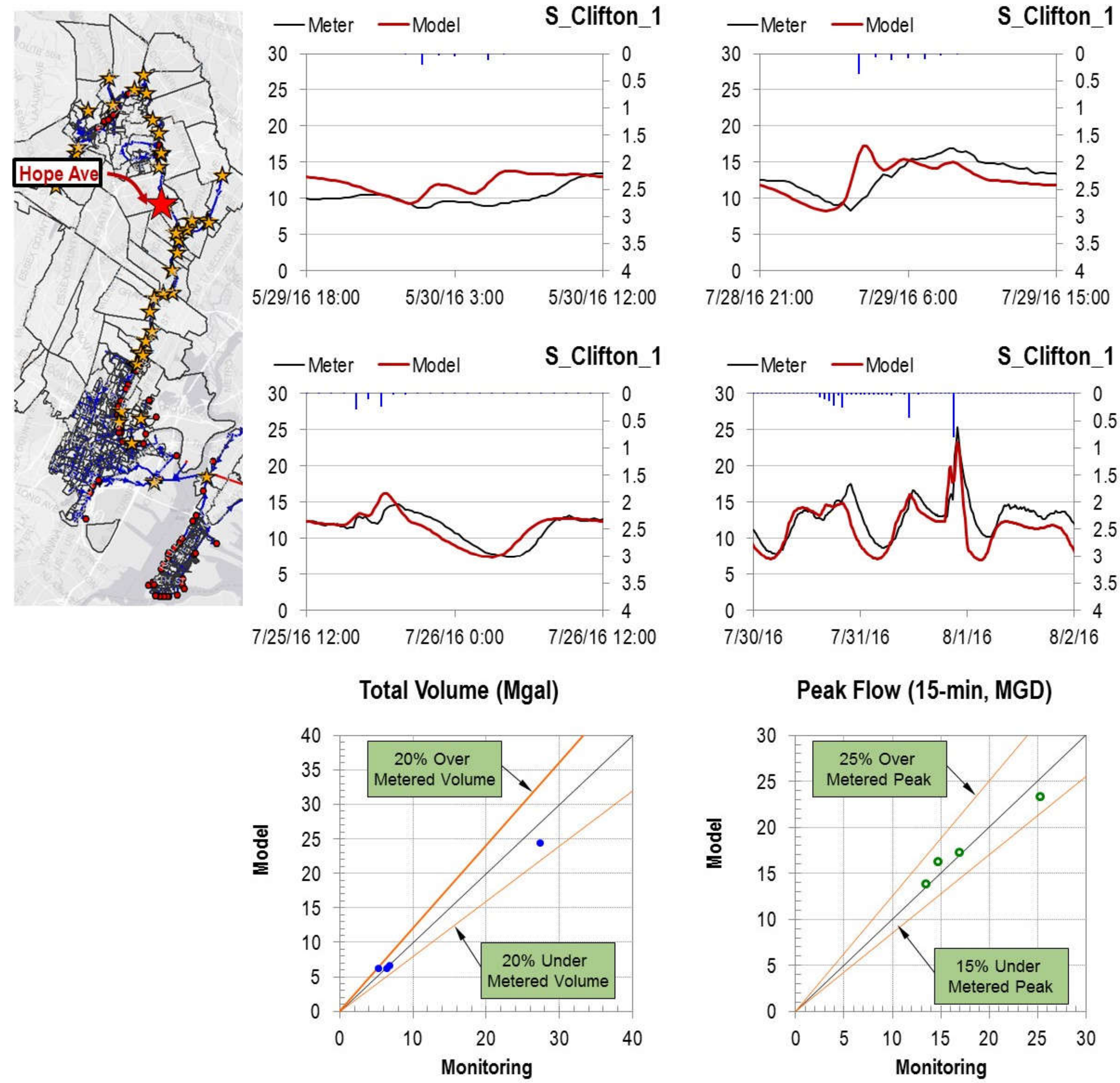


Figure I-30: Calibration Plot for Separate Area_Hope Ave

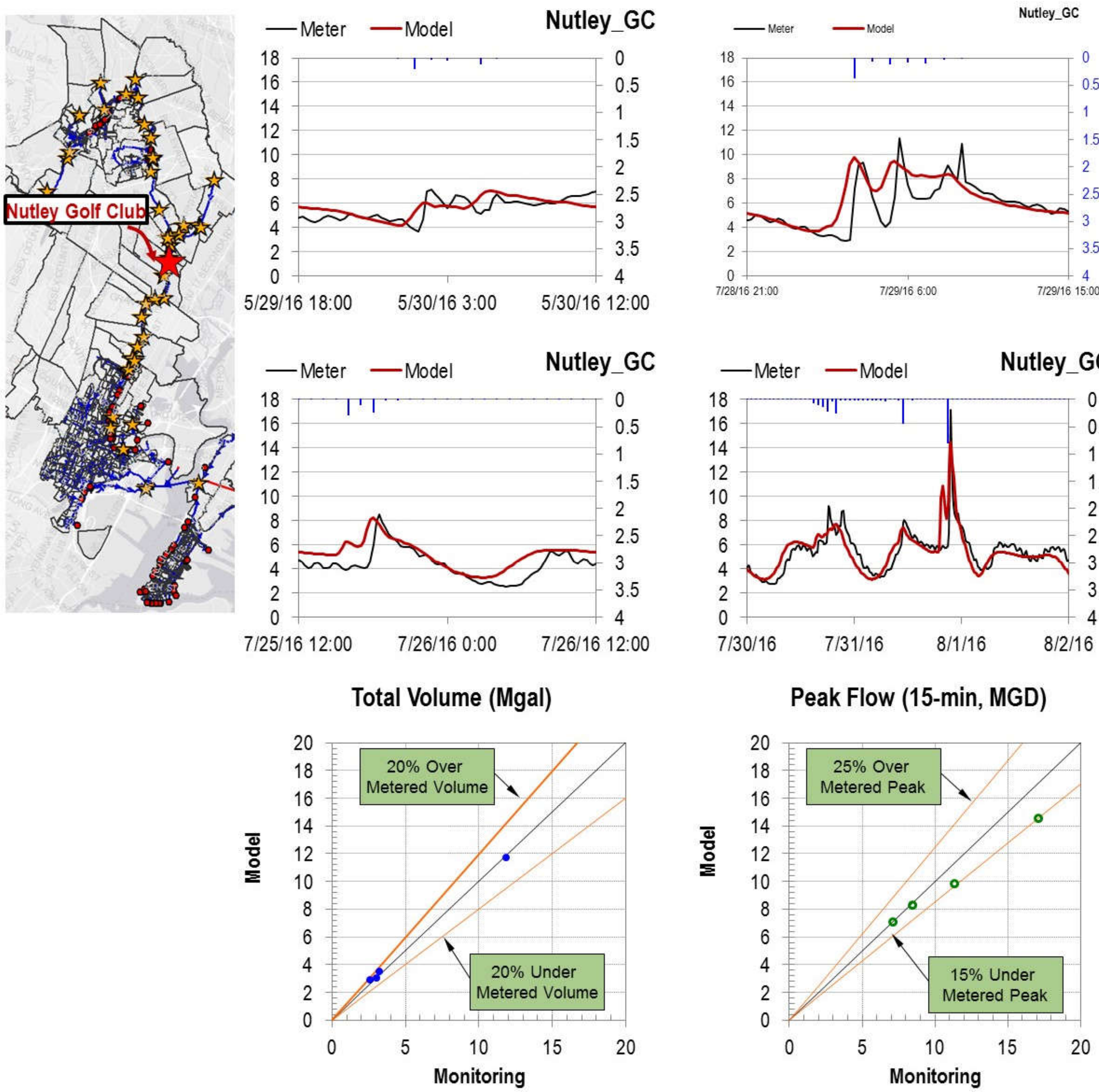


Figure I-31: Calibration Plot for Separate Area_Nutley Golf Club

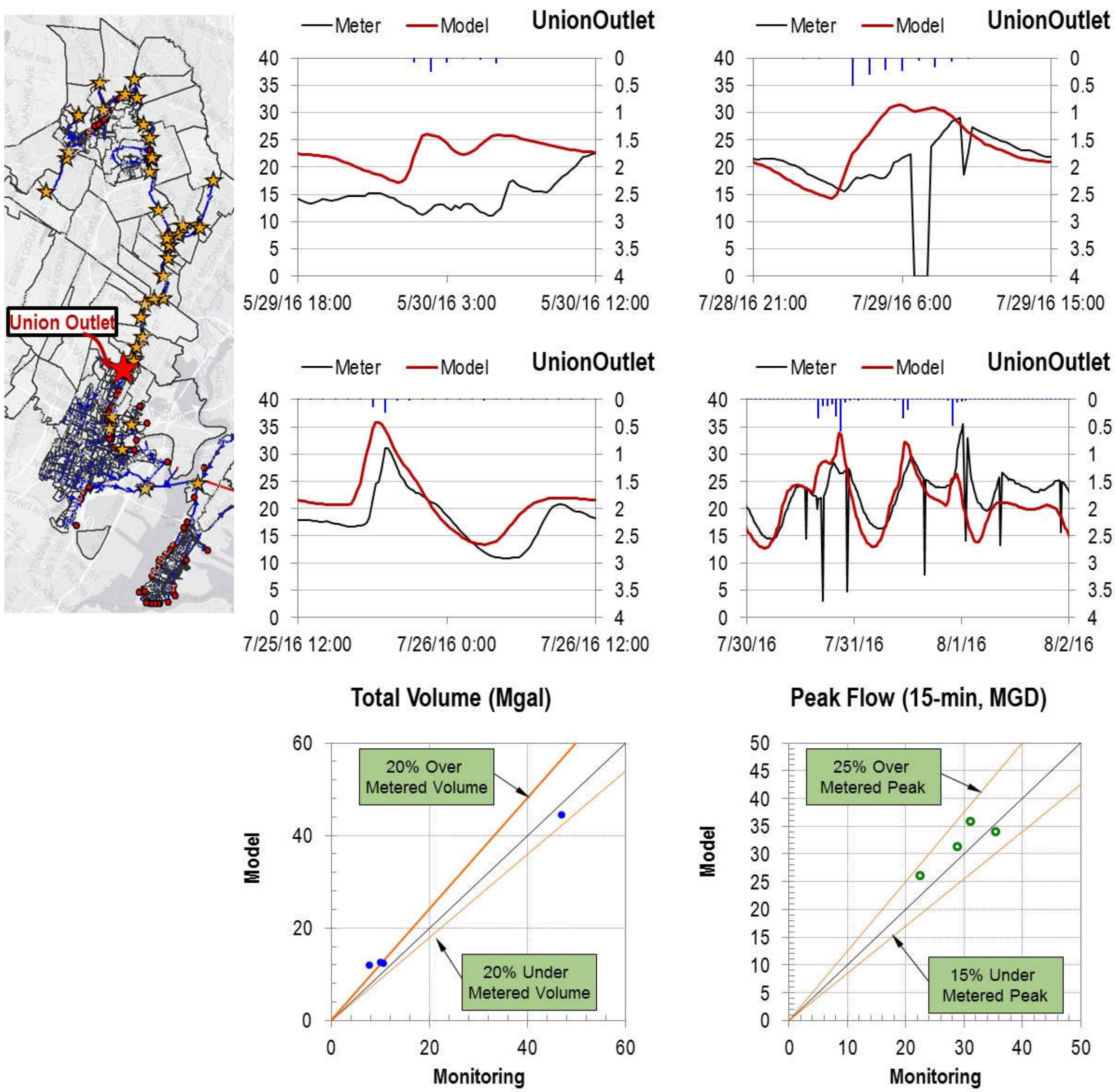


Figure I-32: Calibration Plot for Separate Area_Union Outlet

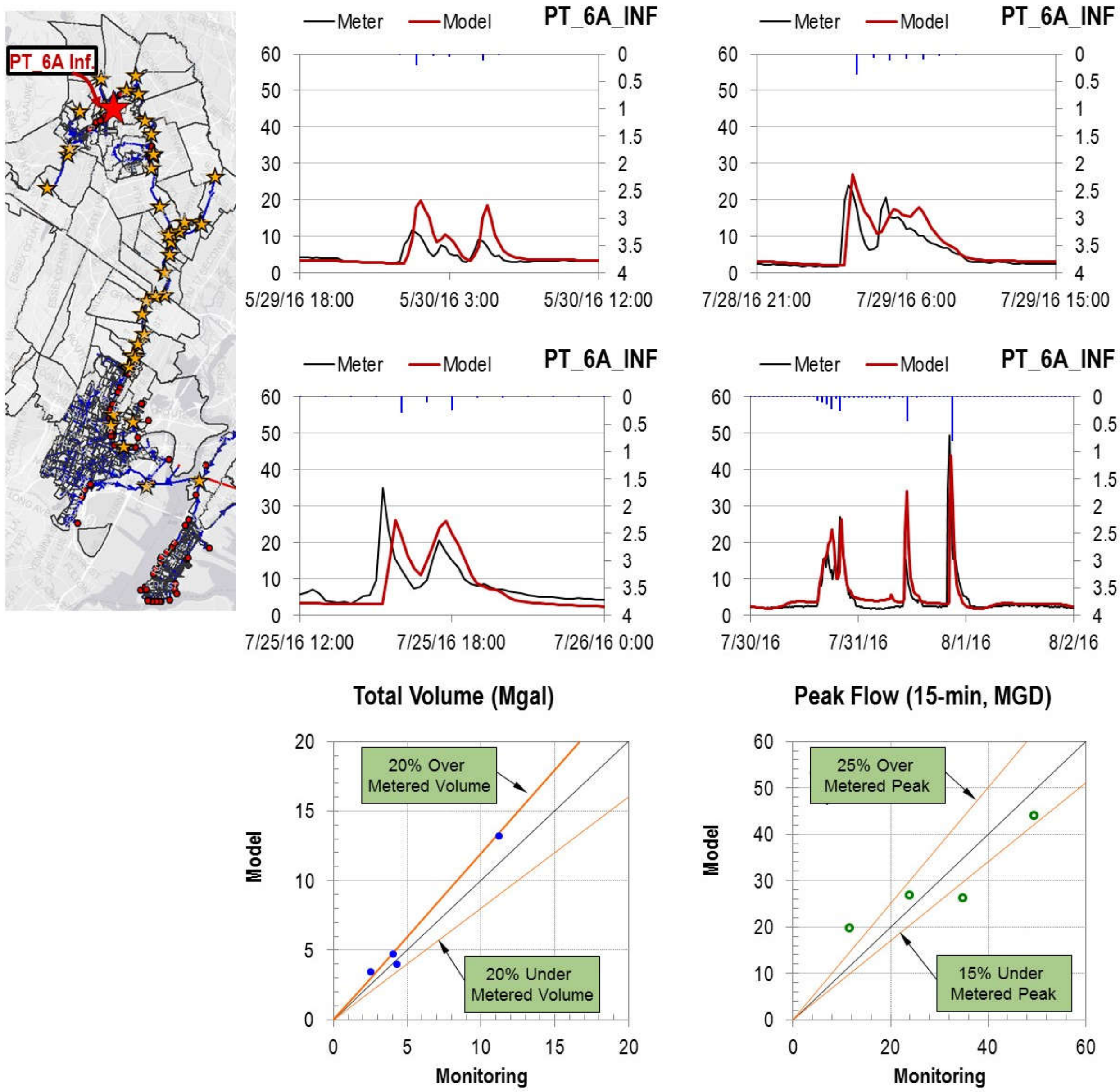


Figure I-33: Calibration Plot for Combined Area_Paterson 6A Influent

Note:
The simulated volume and peak flow for the May 29, 2016 event exceeded the monitored values beyond the targeted calibration ranges. Adjusting the model parameters to provide a better fit for this event would have resulted in under simulation of the larger events.

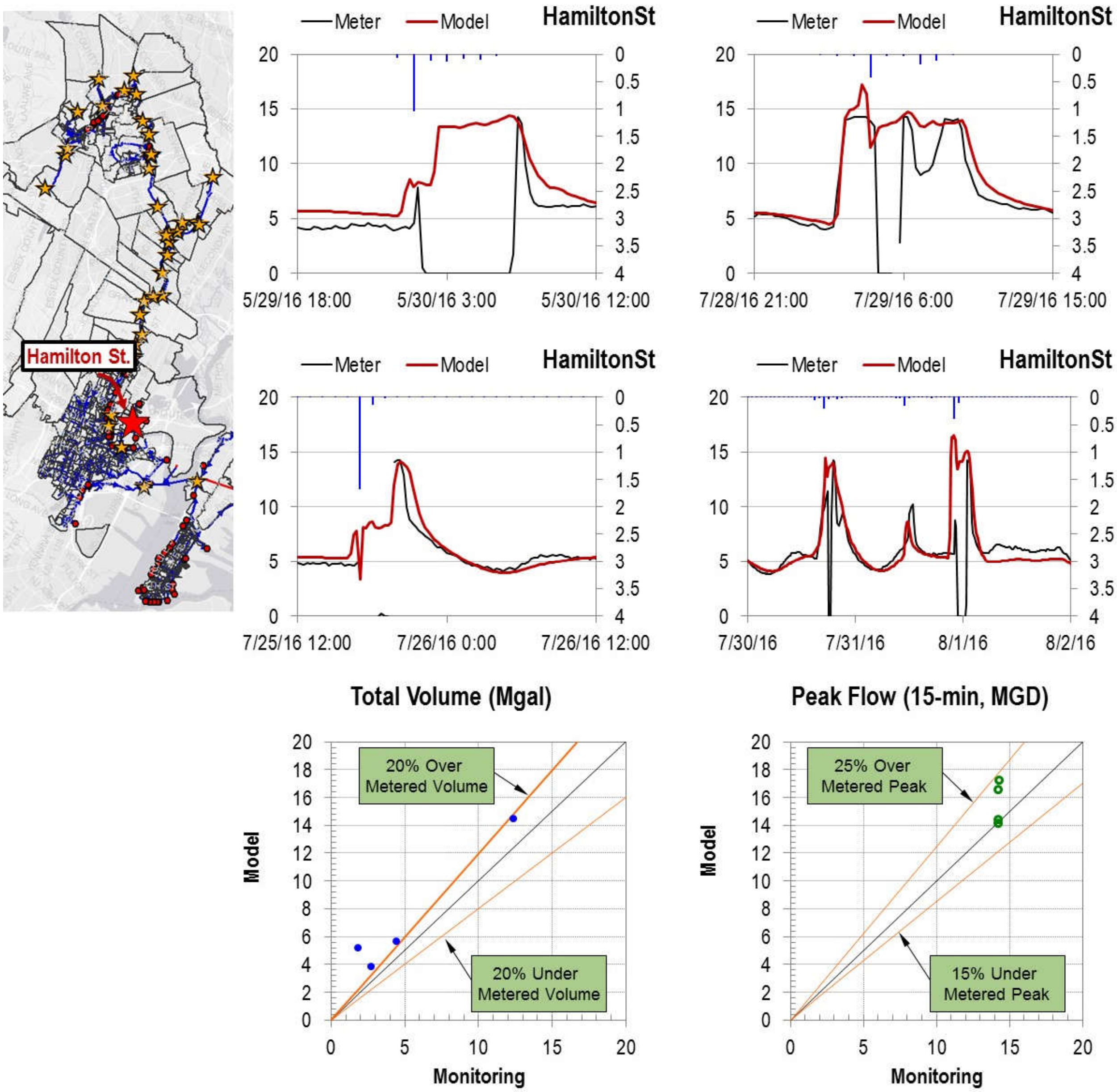


Figure I-34: Calibration Plot for Combined Area_ Hamilton St.

Note:

1. Monitored data was not available for an extended portion of the May 29th, 2016 event. Therefore, this event was not considered during model calibration.
2. The monitored data for the July 29th, 2016 and July 30th, 2016 events also has some missing or periods of zero flow. The calibration effort for this site focused on matching peak flows and the hydrograph pattern.

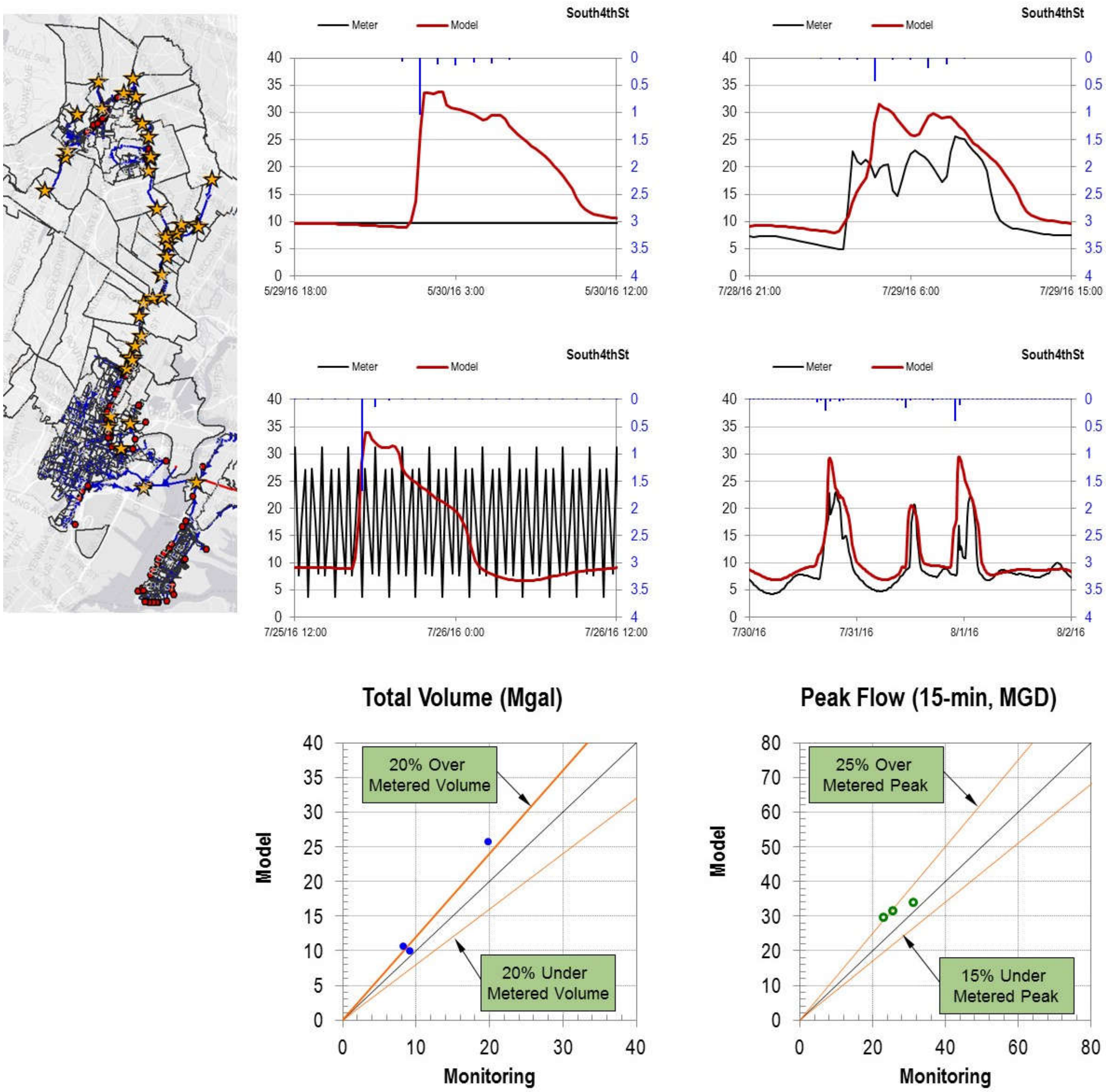


Figure I-35: Calibration Plot for Combined Area_ South 4th St.

Note:

1. Accurate monitoring data was not available for the May 29th, 2016 event. Therefore, this event was not considered during model calibration and is not shown on the one-to-one plots.
2. Monitored data for Event July 25, 2016 has significant fluctuations and was therefore not considered during model calibration.

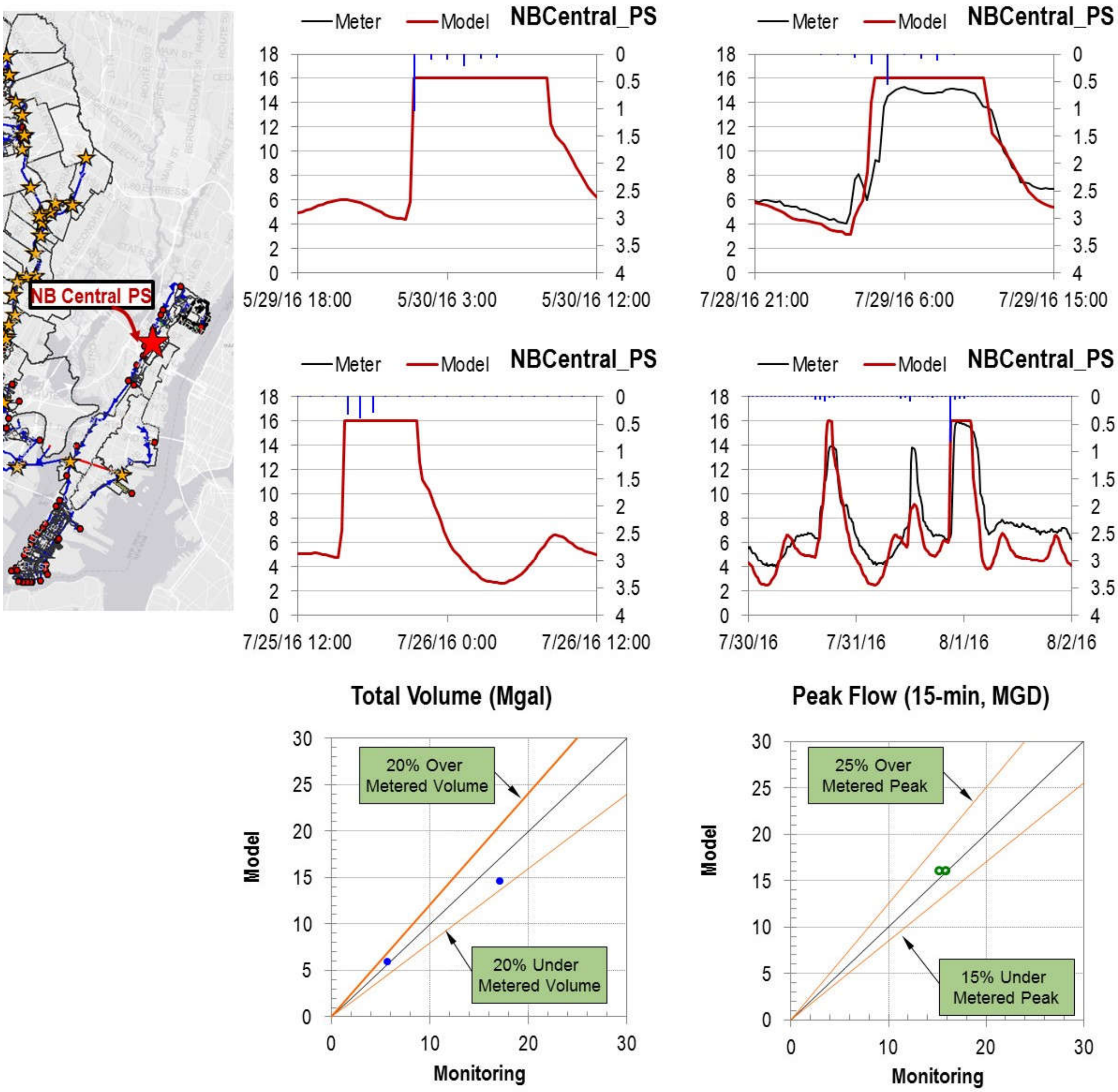


Figure I-36: Calibration Plot for Combined Area_ NB Central Pump Station

Note:

1. Monitored data was not available for the May 29th, 2016 and July 25, 2016 events. Therefore, these events were not considered during model calibration and are not shown on the one-to-one plots.

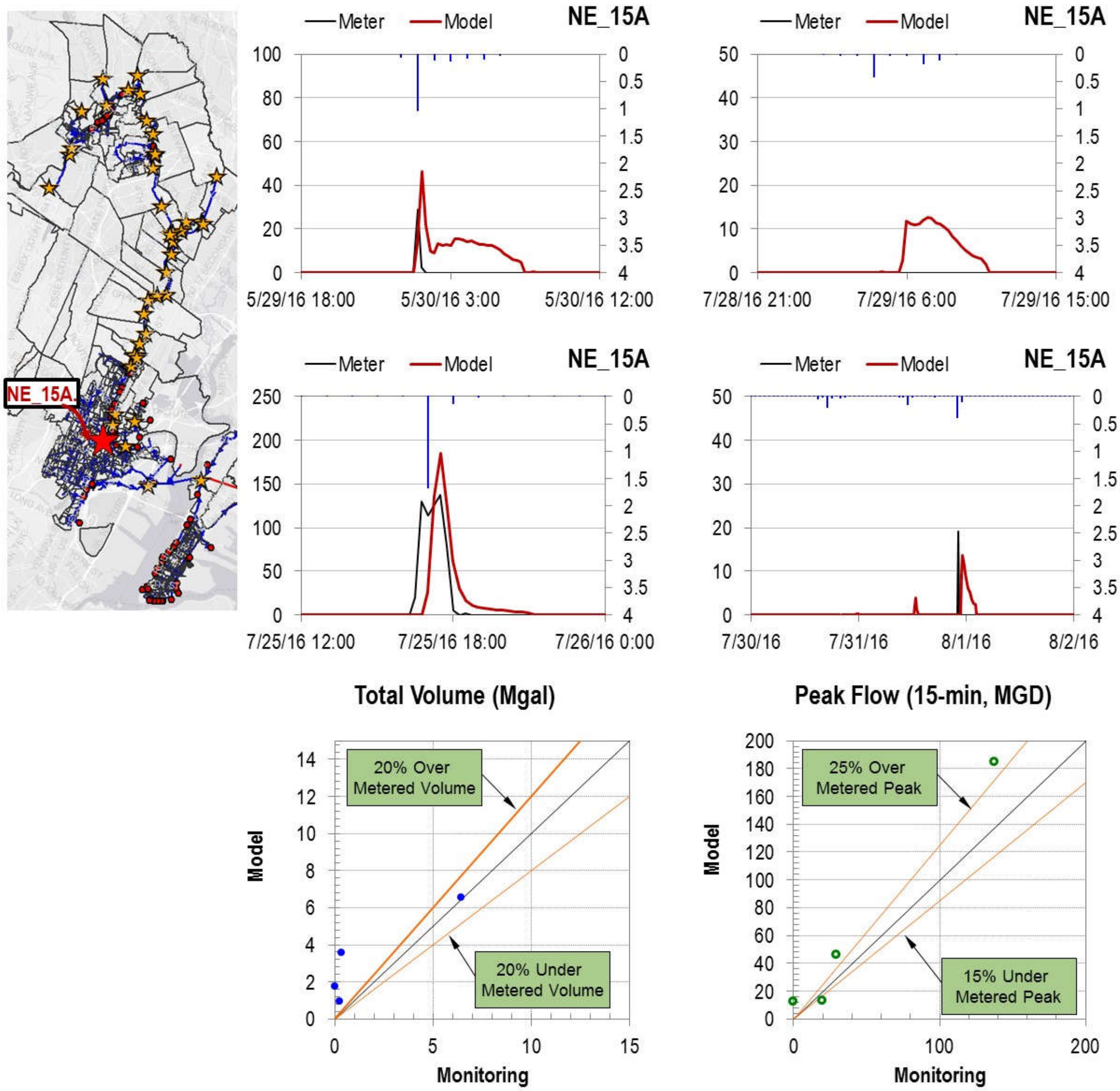


Figure I-37: Calibration Plot for CSO Overflow_ NE_15A

Note:

1. Calibration efforts were focused on the July 25, 2016 event because it had the most appropriate rainfall response and as the largest event has the most significant impact on overflows. The model is producing overflows during smaller precipitation increments which are not reflected in the monitoring data.

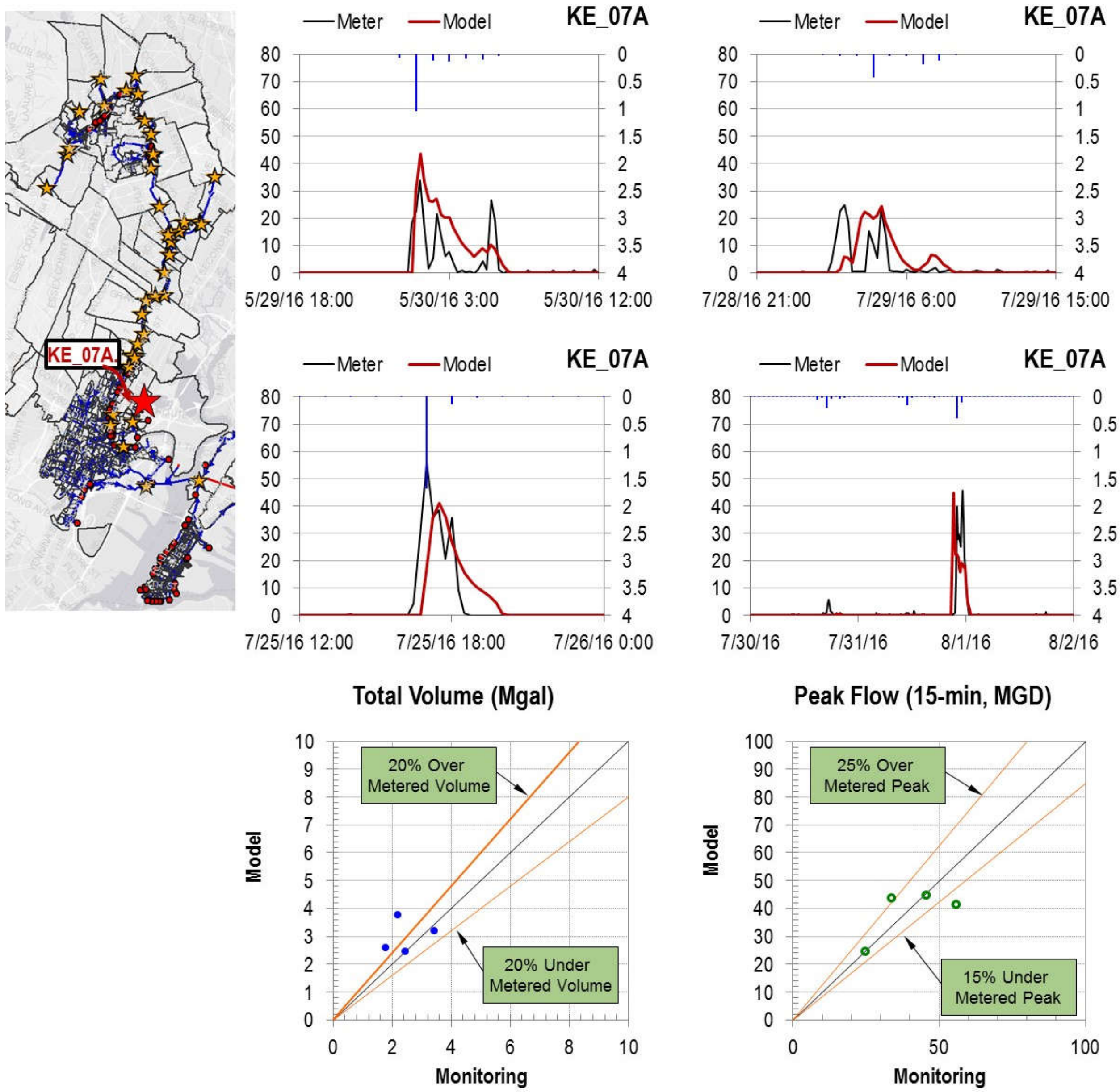


Figure I-38: Calibration Plot for CSO Overflow_ KE_07A

Note:

1. The calibration was performed to have a balanced calibration on both overflow volume and peak (both on conservative side).

I.6 H&H MODEL RESULTS

The calibrated model was simulated for the 2004 typical year to evaluate collection system performance under existing conditions.

Five-minute precipitation data was developed from 1-minute NOAA ASOS (Automated Surface Observing System, National Centers for Environmental Information) for Newark. Minor gaps in the 5-minute data were filled using corresponding hourly and daily data for the airport. The same precipitation data was applied uniformly system wide.

Model results were extracted for all CSO overflow points and for WRRF and other community effluent flows at 15-minute intervals. A 12-hour inter-event-time was used for overflow event definition.

I.6.1 Characterization of System Performance

Under existing conditions, CSO occurs in all communities at a storm depth of 0.2 to 0.3 inches (**Figure I-39**).

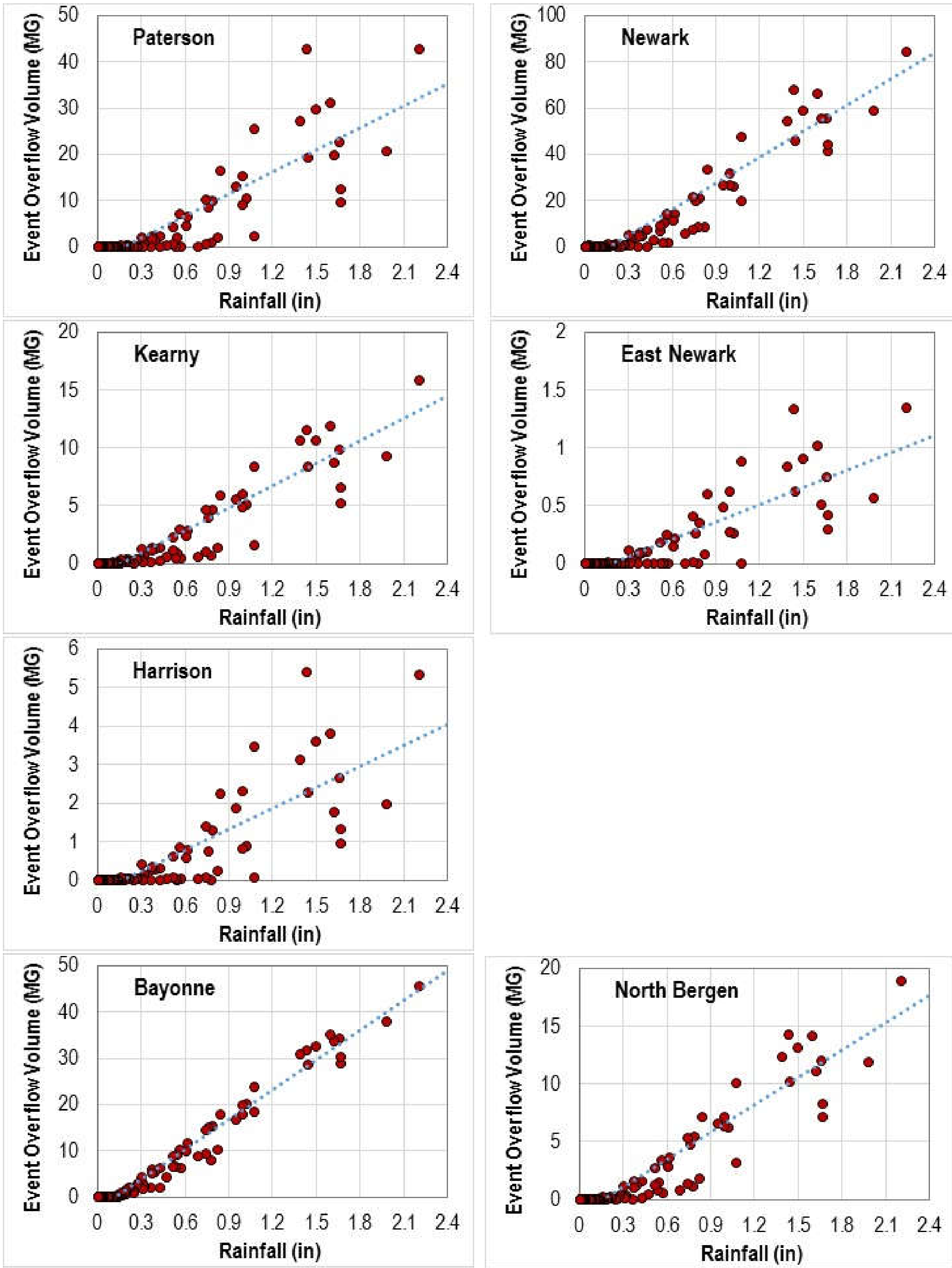


Figure I-39: Correlation Between Rainfall Depth and CSO Overflow Volume

I.6.2 Overflow Statistics

Typical year CSO volume and frequency is summarized in **Table I-12**, **Figure I-40**, **Figure I-41** and **Figure I-42**.

Table I-12: Typical Year CSO Overflow Volume and Frequency

CSO ID	Overflow Volume (MG)	Overflow Frequency	CSO ID	Overflow Volume (MG)	Overflow Frequency	CSO ID	Overflow Volume (MG)	Overflow Frequency
PT001	24.9	38	EN001	16.8	39	NB003	171.3	51
PT003	1.8	20	HR001	1.4	30	NB005	30.1	55
PT005	6.5	27	HR002	2.9	34	NB006	0.0	0
PT006	76.6	38	HR003	13.7	33	NB007	6.6	32
PT007	42.8	37	HR005	18.9	36	NB008	15.1	30
PT010	9.7	26	HR006	6.8	30	NB009	25.6	45
PT013	11.4	29	HR007	13.3	49	NB010	1.2	25
PT014	0.1	5	KE001	3.9	33	NB011	5.1	37
PT015	0.5	18	KE004	12.3	58	NB014	0.5	7
PT016	12.3	30	KE006	119.3	63	BA001	373.8	70
PT017	8.7	33	KE007	86.1	36	BA002	8.6	9
PT021	5.0	30	KE010	26.0	54	BA003	11.0	34
PT022	17.4	33	NE002	91.5	46	BA004	0.0	3
PT023	3.0	17	NE003	0.0	0	BA006	16.0	37
PT024	8.3	31	NE004	1.4	23	BA007	72.2	37
PT025	88.0	56	NE005	21.2	43	BA008	10.1	34
PT026	0.5	15	NE008	93.2	52	BA009	4.2	33
PT027	40.9	46	NE009	164.0	42	BA010	17.4	53
PT028	10.0	28	NE010	164.0	42	BA011	5.9	34
PT029	92.4	48	NE014	180.1	52	BA012	14.0	57
PT030	4.4	4	NE015	74.6	43	BA013	0.8	33
PT031	9.5	27	NE016	54.3	49	BA014	12.6	43
PT032	30.2	32	NE017	107.3	51	BA015	46.6	54
			NE018	75.6	53	BA016	6.5	48
			NE022	45.7	69	BA017	54.2	62
			NE023	16.8	35	BA018	14.6	58
			NE025	58.2	16	BA019	38.8	35
			NE026	16.6	17	BA020	10.1	33
			NE027	11.3	17	BA021	62.9	54
			NE030	10.3	19	BA022	0.0	0
						BA024	0.1	3
						BA026	1.3	9
						BA028	0.0	0
						BA029	6.8	24
						BA030	1.5	16
						BA034	0.1	7
						BA037	1.0	8

Duration of each discharge for each CSO in number of days under Compliance Monitoring Program (CMP) can be found in the monthly Discharge Monitoring Reports (DMRs) that are submitted by the each CSO Permittees each month to the NJDEP.

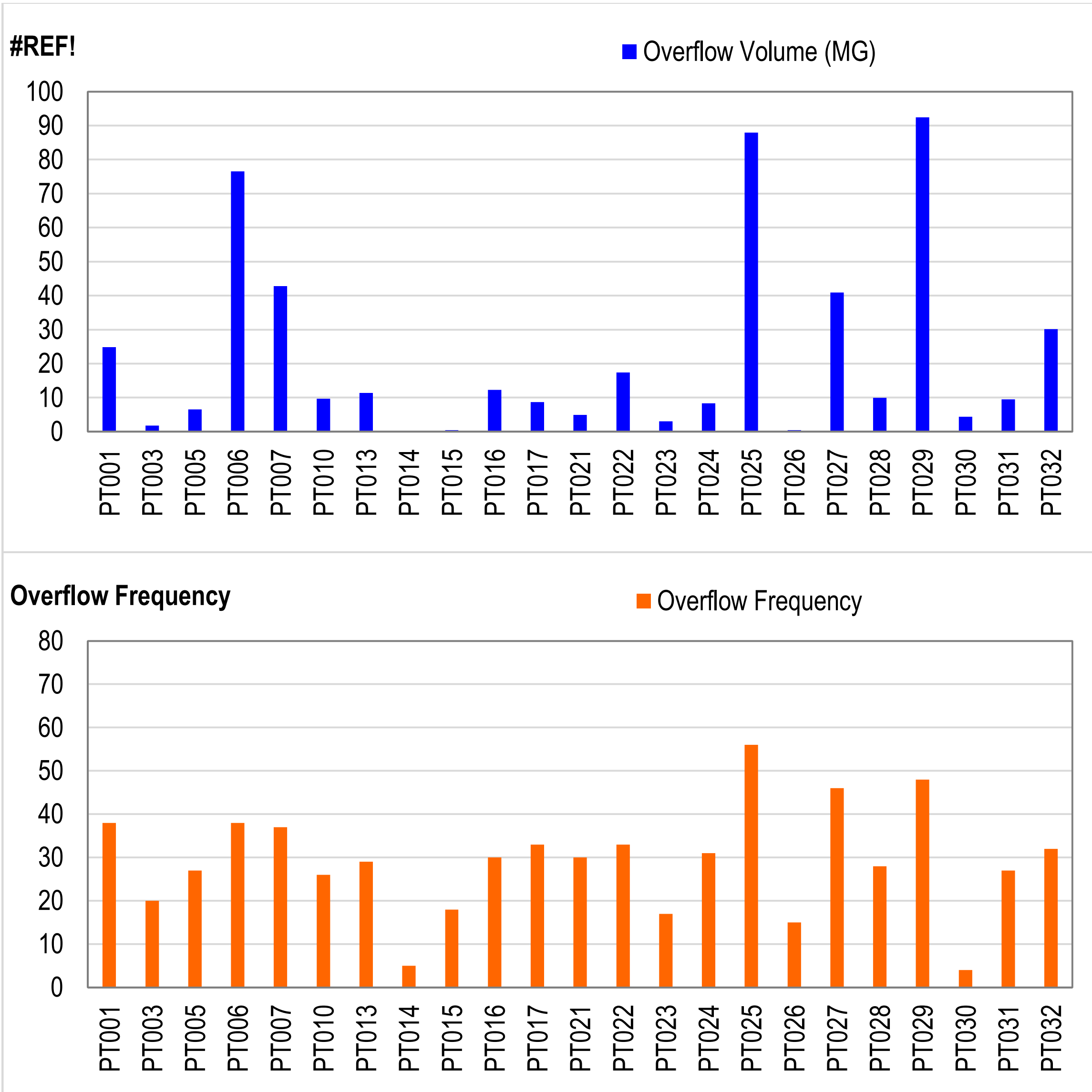


Figure I-40: Typical Year CSO Overflow Volume and Frequency Paterson

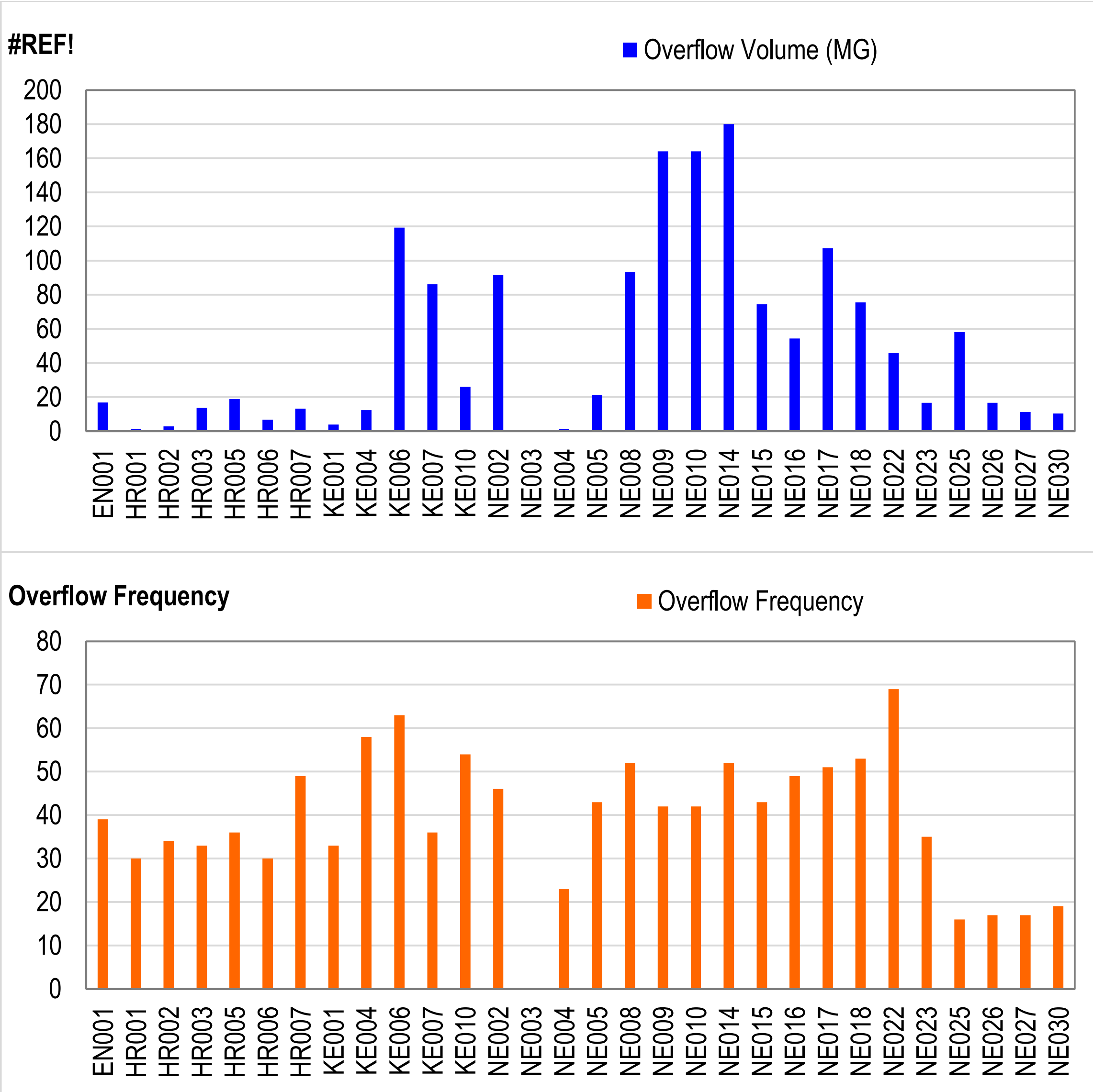


Figure I-41: Typical Year CSO Overflow Volume and Frequency East Newark, Harrison, Kearny and Newark

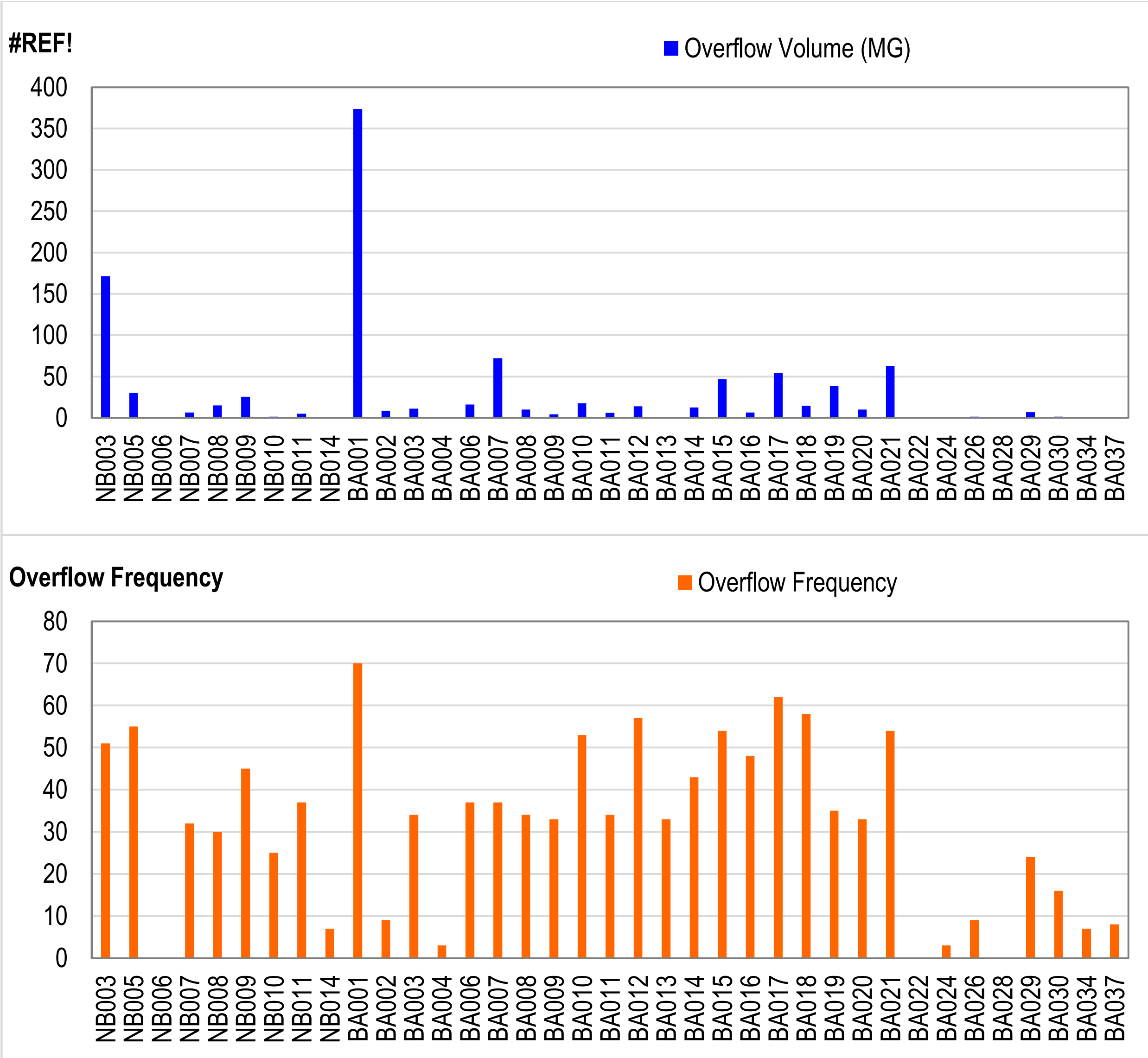


Figure I-42: Typical Year CSO Overflow Volume and Frequency North Bergen and Bayonne

I.6.3 Percent Capture

Wet weather percent capture was calculated for the PVSC Interceptor communities, North Bergen, and Bayonne. The wet weather volume was estimated based on durations from the time when the accumulated precipitation depth is over 0.1 inch to 12 hours after the storm event.

Table I-13: Typical Year % Capture

	PVSC Interceptor Communities	North Bergen	Bayonne
Total WWF Volume (MG)	12,573	788	1,402
Total CSO Volume (MG)	2,013	256	791
% Capture	84%	68%	44%
Additional Capture Volume (MG) for 85% Capture	127	137	581

SECTION J - REFERENCES

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SECTION K - ABBREVIATIONS

CSO: Combined Sewer Overflow
CSS: Combined Sewer System
CWA: Clean Water Act
DWF: Dry Weather Flow
EPA: United States Environmental Protection Agency
ESI: Environmental Sensitivity Index
GIS: Geographic Information System
H&H: Hydrologic and Hydraulic
LTCP: Long Term Control Plan
MGD: million gallons per day
NJPDES New Jersey Pollutant Discharge Elimination System
PCBs: polychlorinated biphenyls
QAPP: Quality Assurance Project Plan
SSS: Separate Sewer System
USEPA: United States Environmental Protection Agency
WRRF: Water Resources Recovery Facility

APPENDIX A

Combined Sewer Overflow and Stormwater Sampling Results

APPENDIX A

Sampling Schedule and Dates

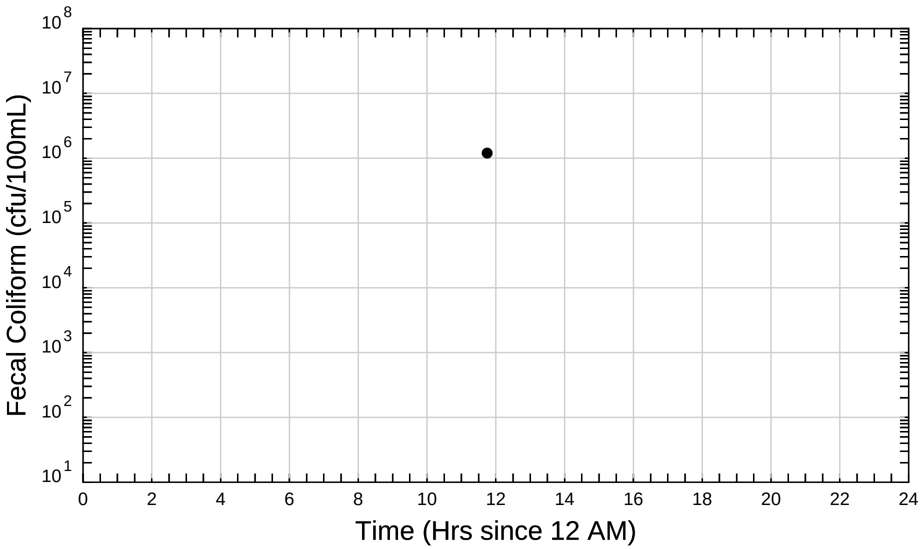
A summary of the sampling dates with corresponding locations and sample station identification numbers are shown in the table below. The Sampling Identification is noted at the top of each page in Appendix A.

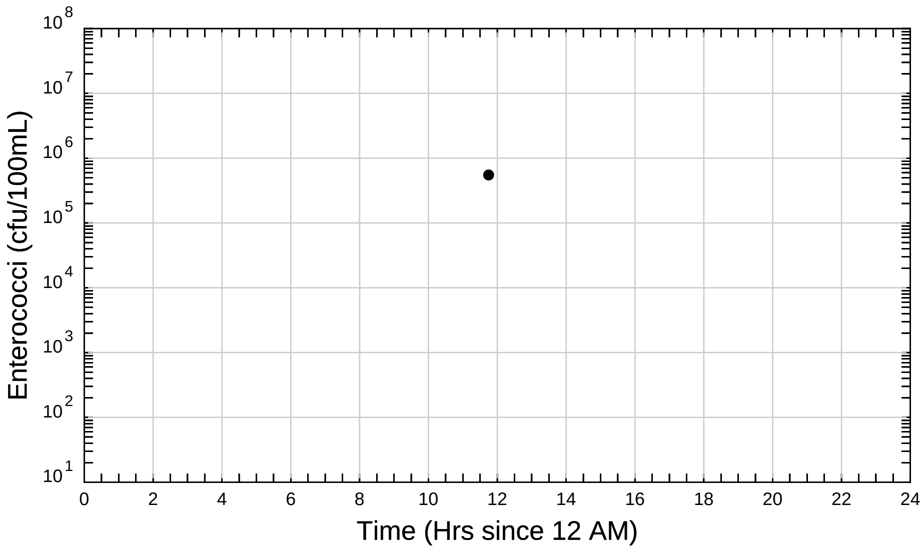
CSO Sampling		
Date	**Locations**	**CSO Sample Identification**
8/21/2016	1	PAT-06A
11/29/2016	5	HAR-06A, HAR-07A, KEA-07A, NWK-25A, NWK-45A
4/4/2017	4	HAR-06A, HAR-07A, KEA-07A, NWK-91A
4/6/2017	4	NWK-14A, NWK-45A, PAT-06A, PAT-29A
6/19/2017	4	BAY-08A, BAY-10A, PAT-25A, PAT-27A
7/13/2017	3	GUT-01A, PAT-25A, PAT-27A
7/22/2017	2	BAY-08A, BAY-10A
10/24/2017	4	NWK-14A, NWK-25A, NWK-45A, NWK-91A
Total	**8**	**Unique CSO Locations**
Total	**27**	**CSO Location-Events**

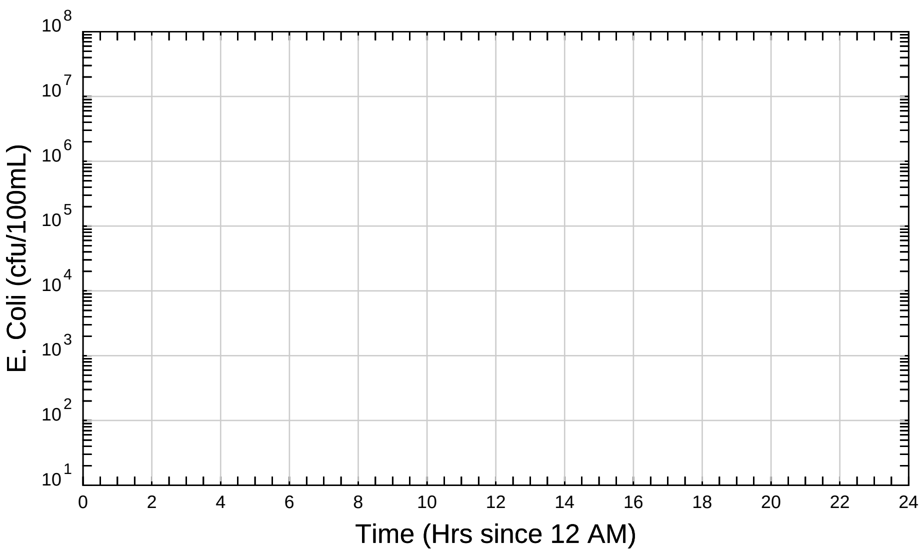
Stormwater Sampling		
Date	**Locations**	**Stormwater Sample Identification**
7/29/2016	2	OAK-LR4, PAT-LR1
9/19/2016	2	NWK-CI2, PAT-LR1
9/30/2016	2	NWK-CI2, OAK-LR4
10/21/2016	1	NWK-HR1
11/15/2016	4	NWK-CI2, NWK-HR1, OAK-LR4, PAT-LR1
12/6/2016	1	NWK-HR1
1/17/2017	2	NWK-HR2, NWK-LR2
5/5/2017	4	HAW-LR3, NWK-HR2, NWK-LR2, PAT-CI1
5/22/2017	2	NWK-HR2, NWK-LR2
5/25/2017	2	HAW-LR3, PAT-CI1
7/6/2017	2	HAW-LR3, PAT-CI1
Total	**11**	**Unique Stormwater Locations**
Total	**24**	**Stormwater Location-Events**

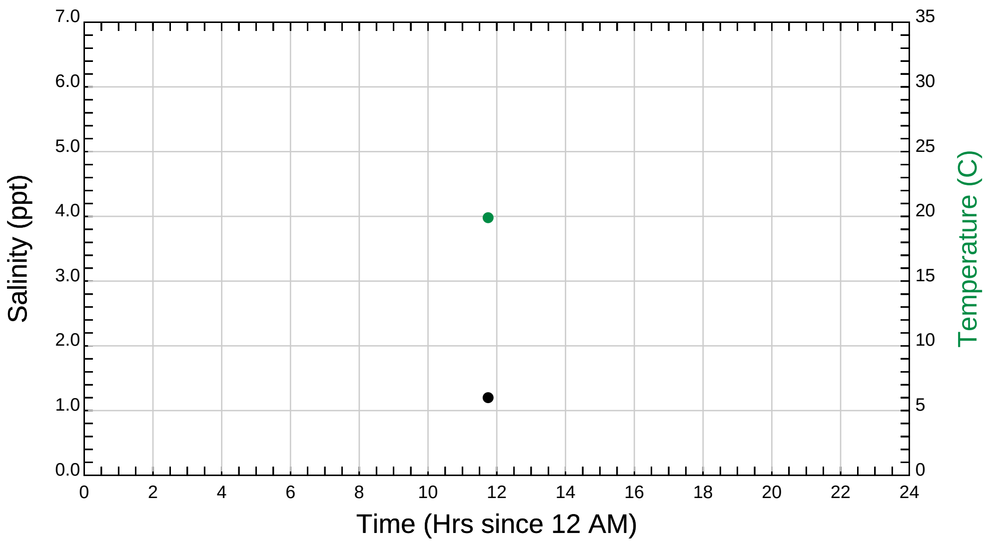
Wet-Weather Event 10. 27.2016.

Station: C1-HAR-06A



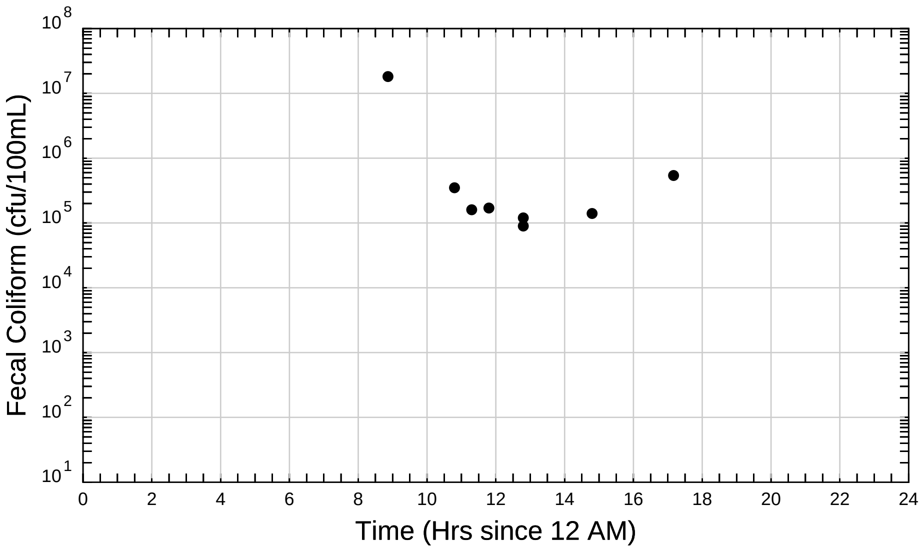


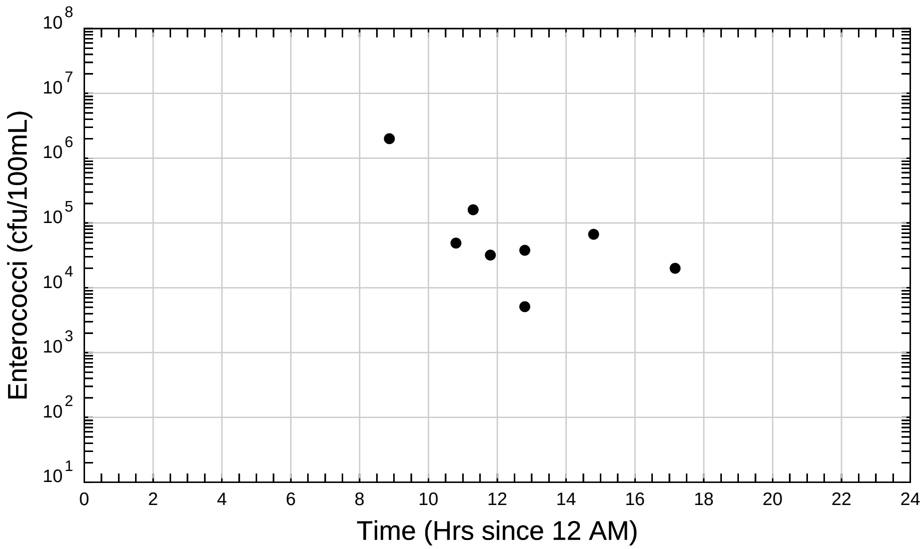


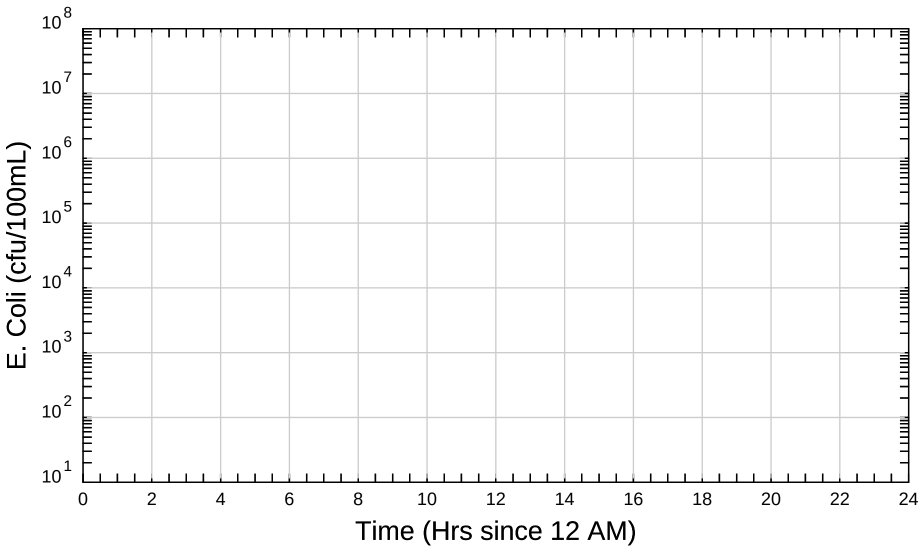


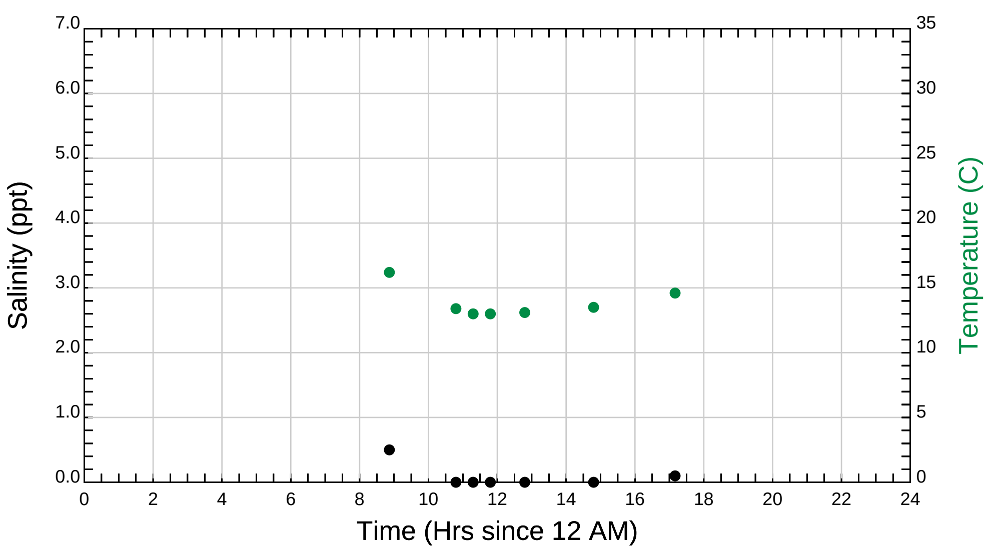
Wet-Weather Event 11. 29. 2016.

Station: C1-HAR-06A



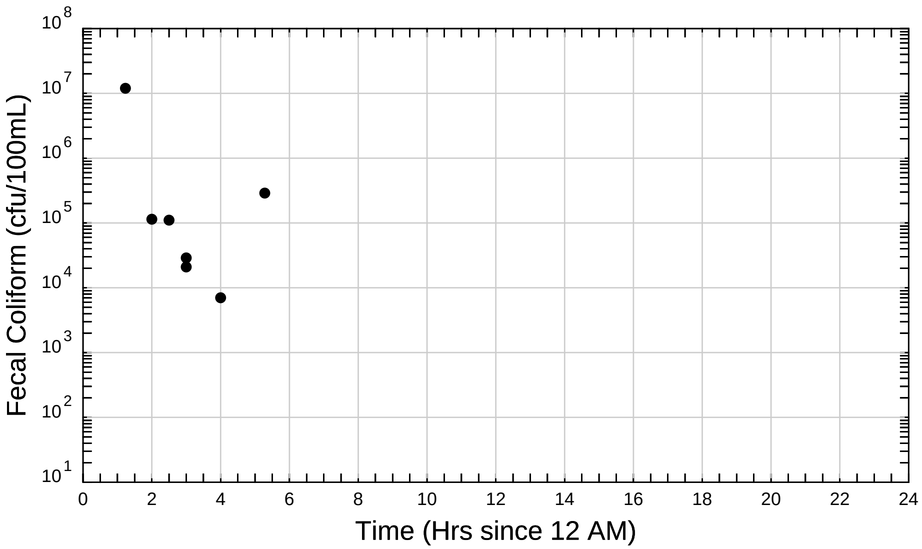


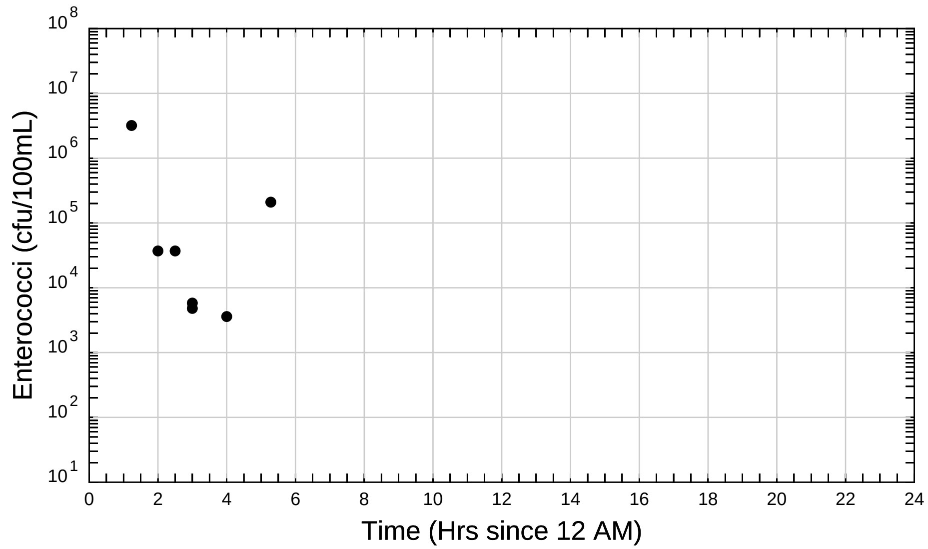


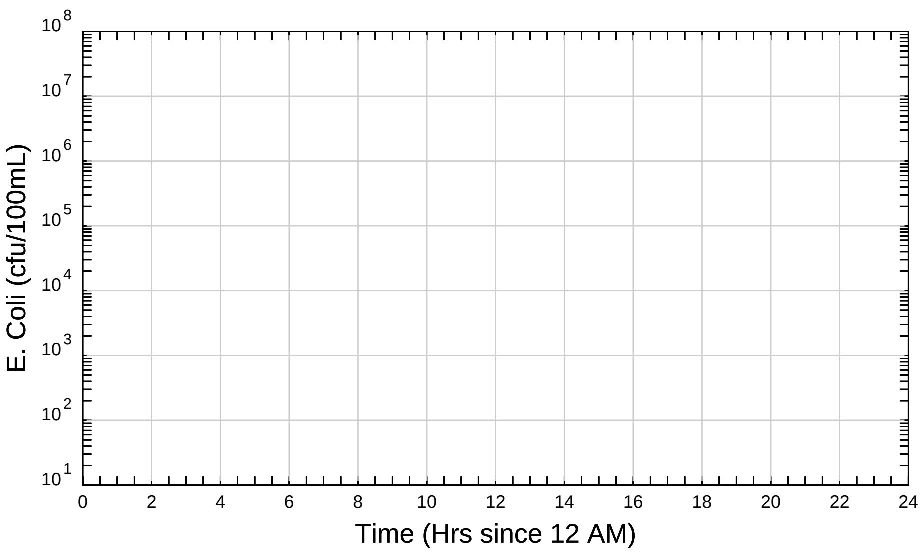


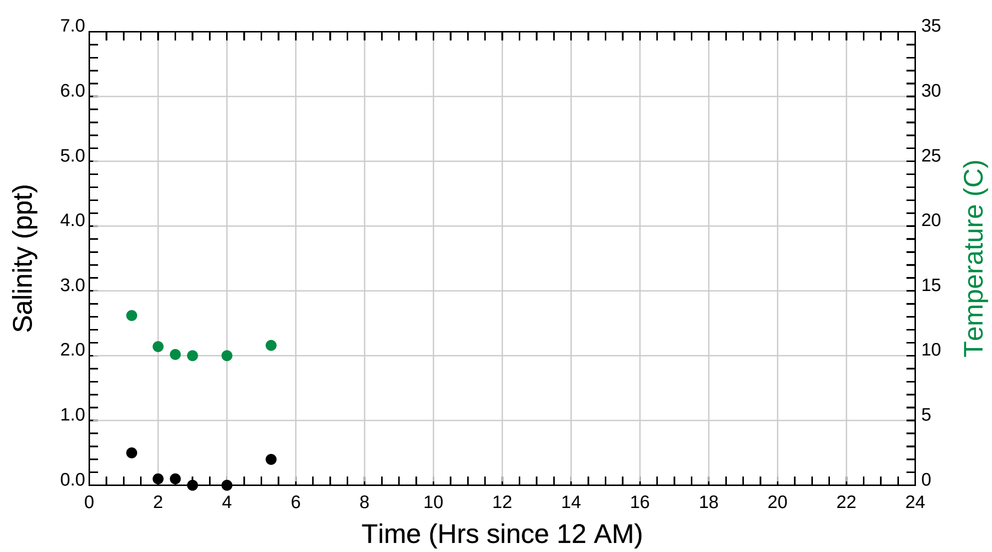
Wet-Weather Event 4. 4.2017.

Station: C1-HAR-06A









Wet-Weather Event 10. 27. 2016.

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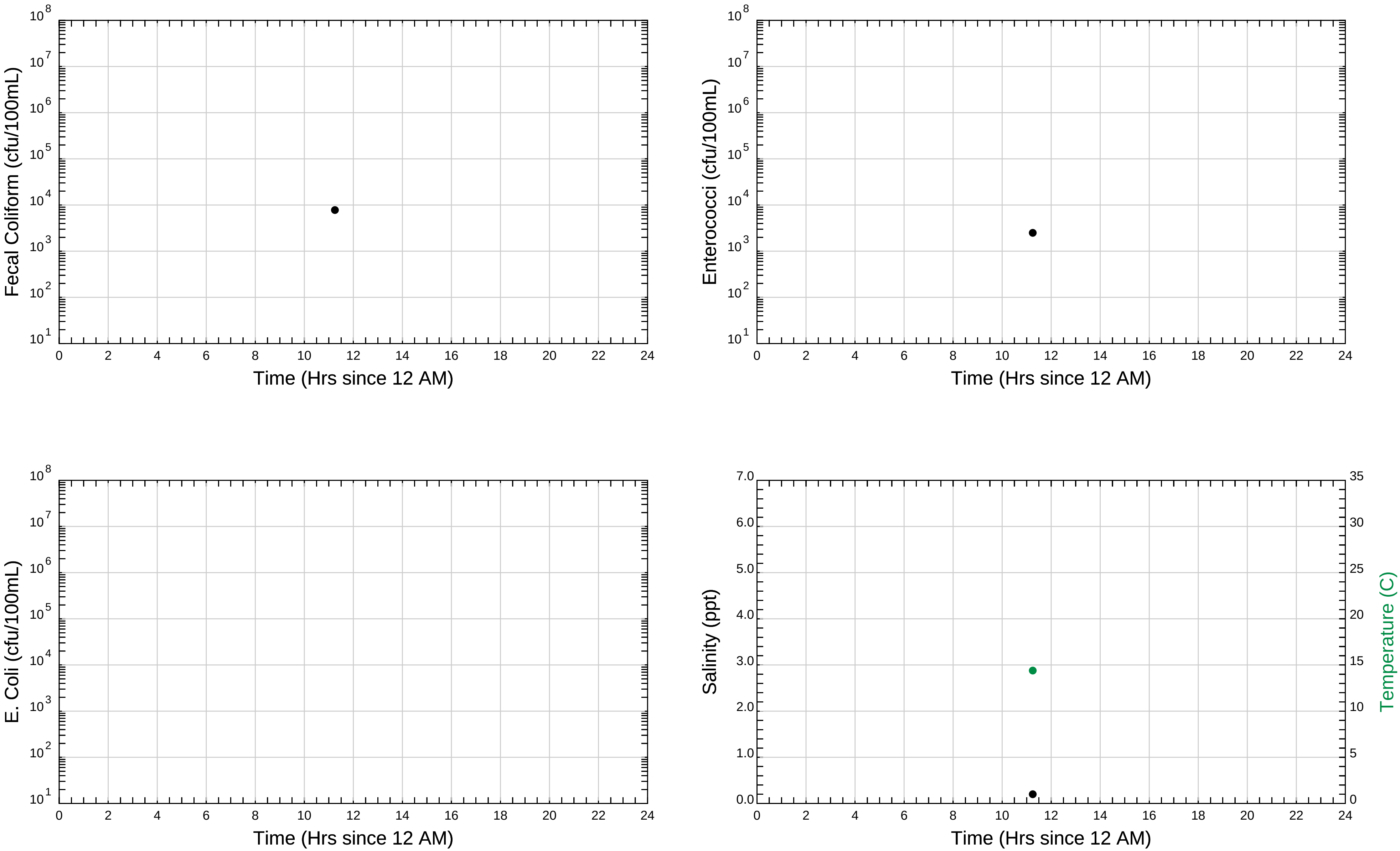

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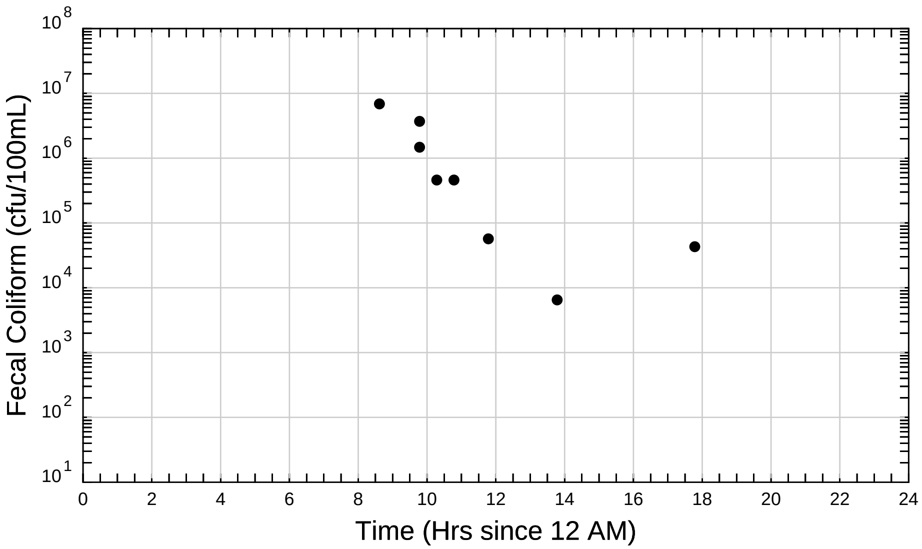
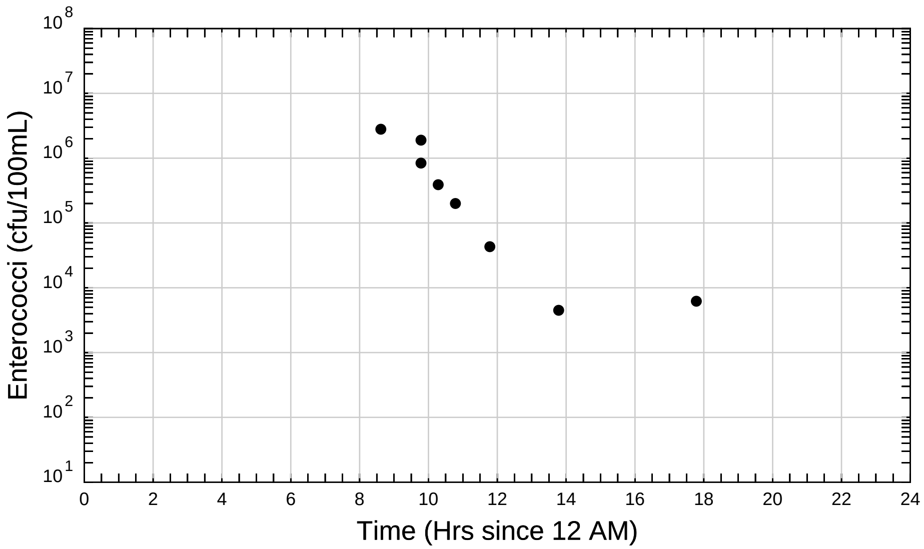
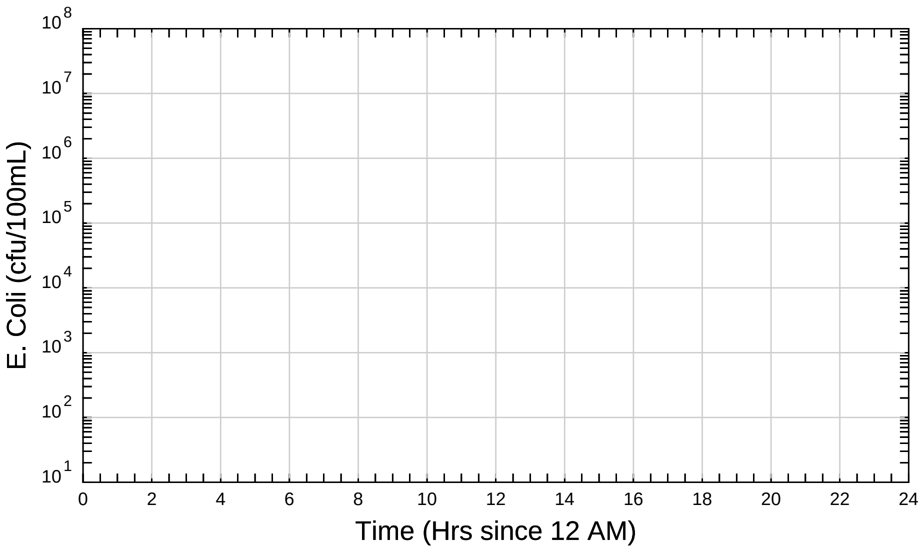
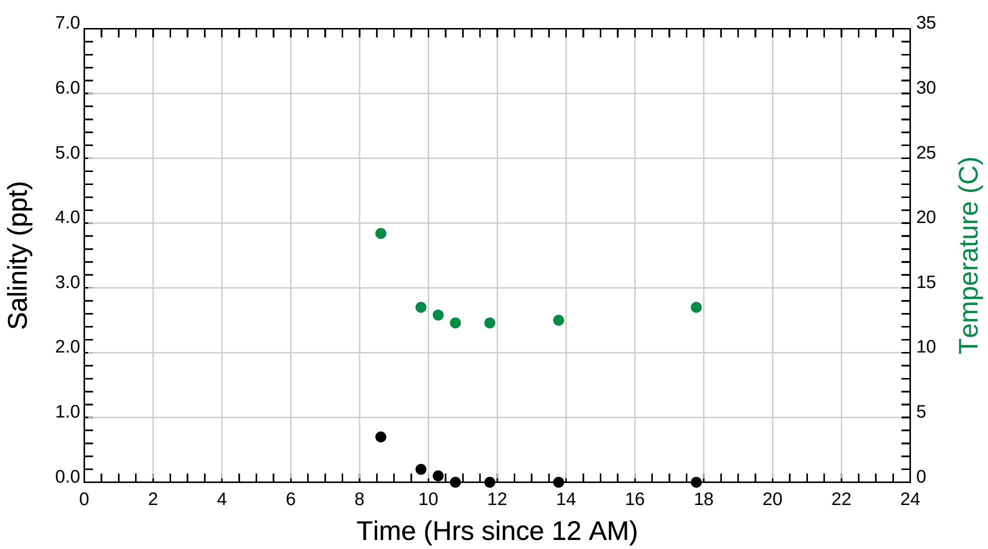


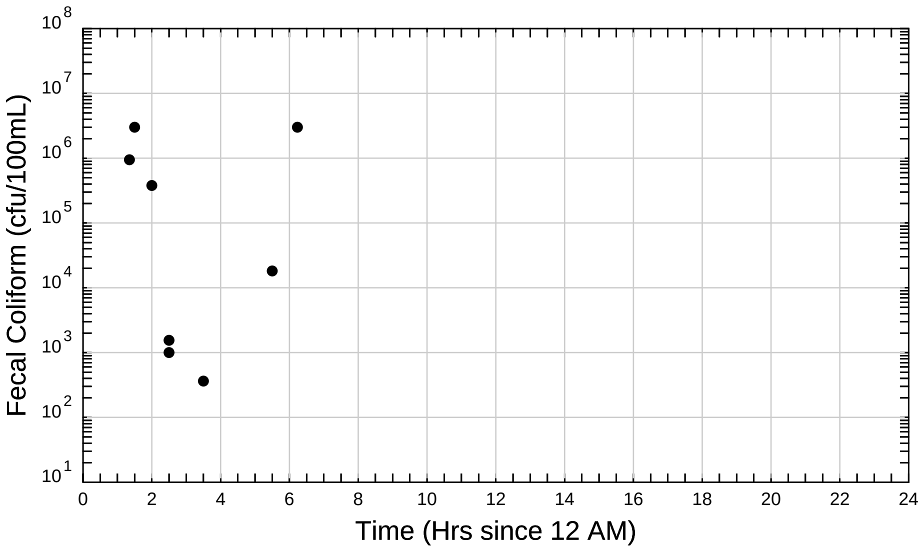


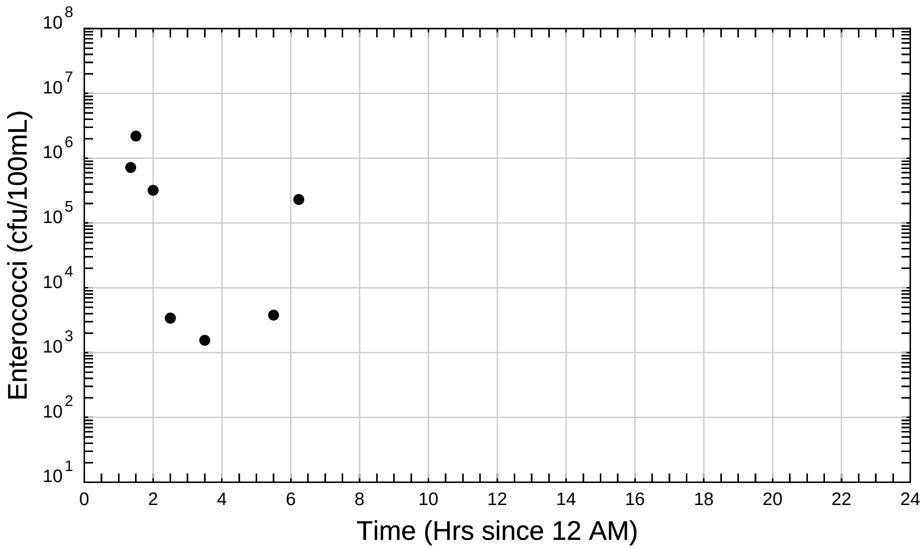


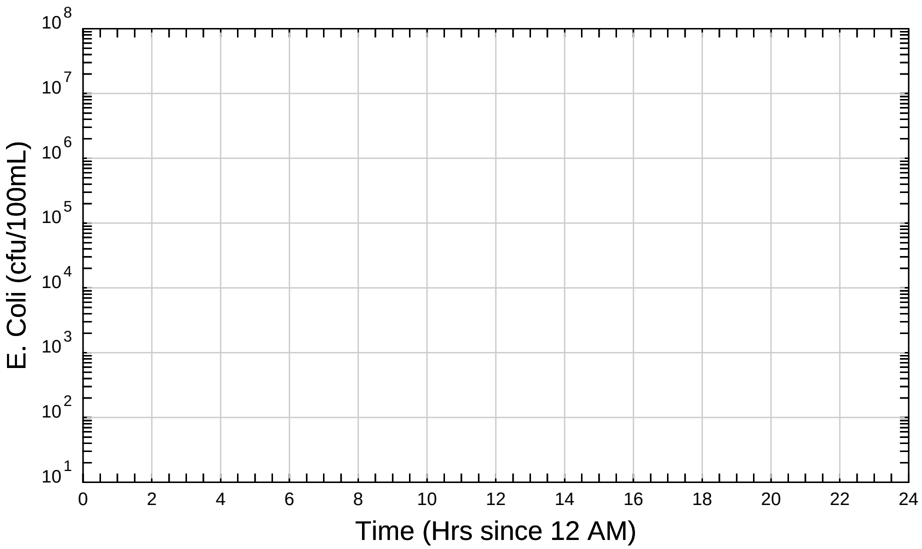


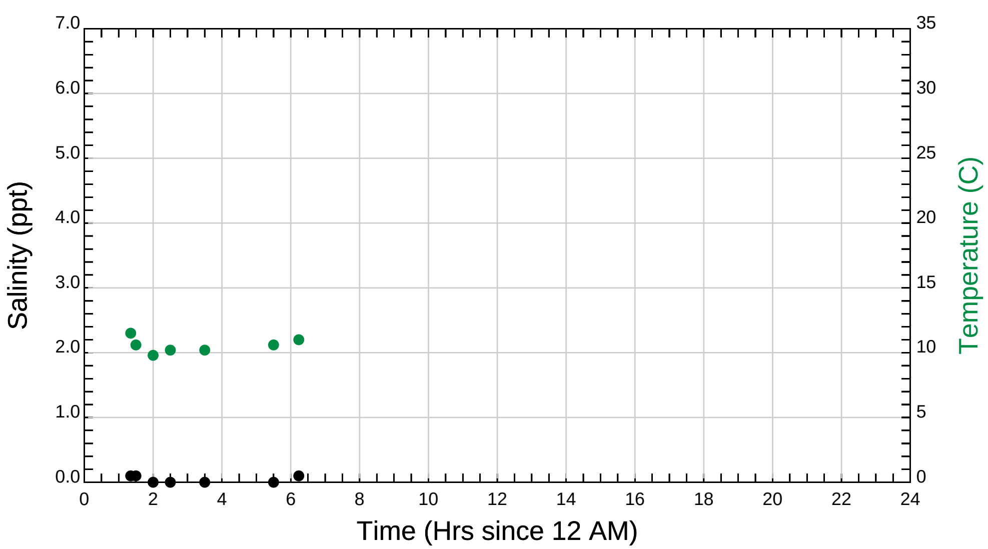
Wet-Weather Event 4. 4.2017.

Station: C1-HAR-07A



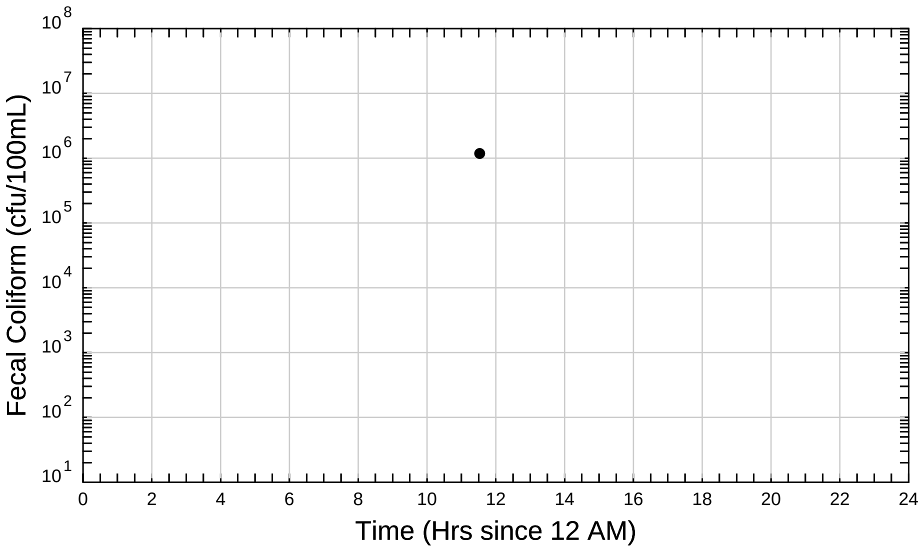


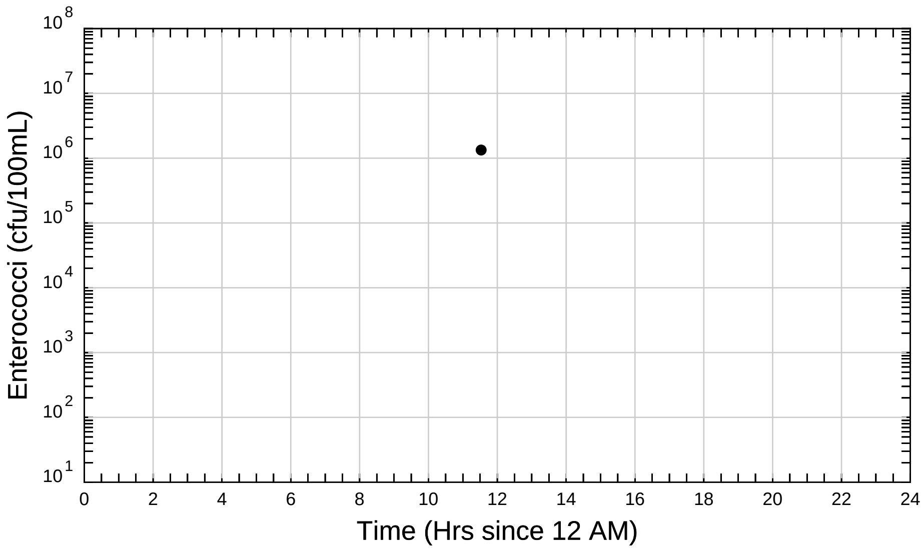


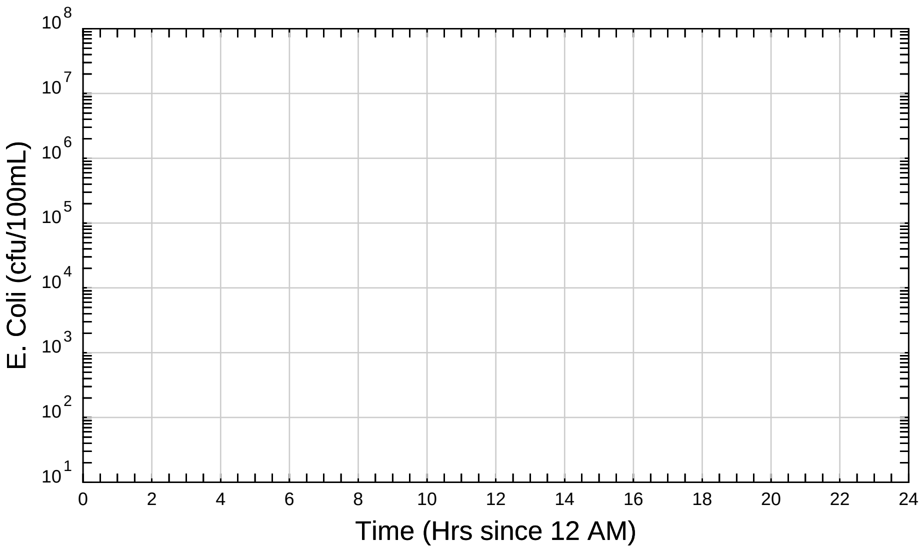


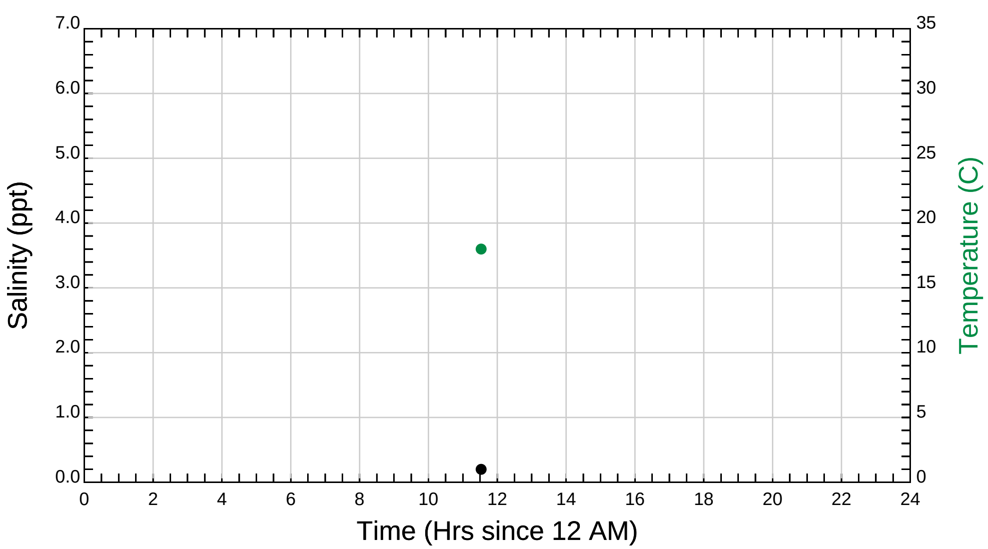
Wet-Weather Event 10. 27.2016.

Station: C1-KEA-07A



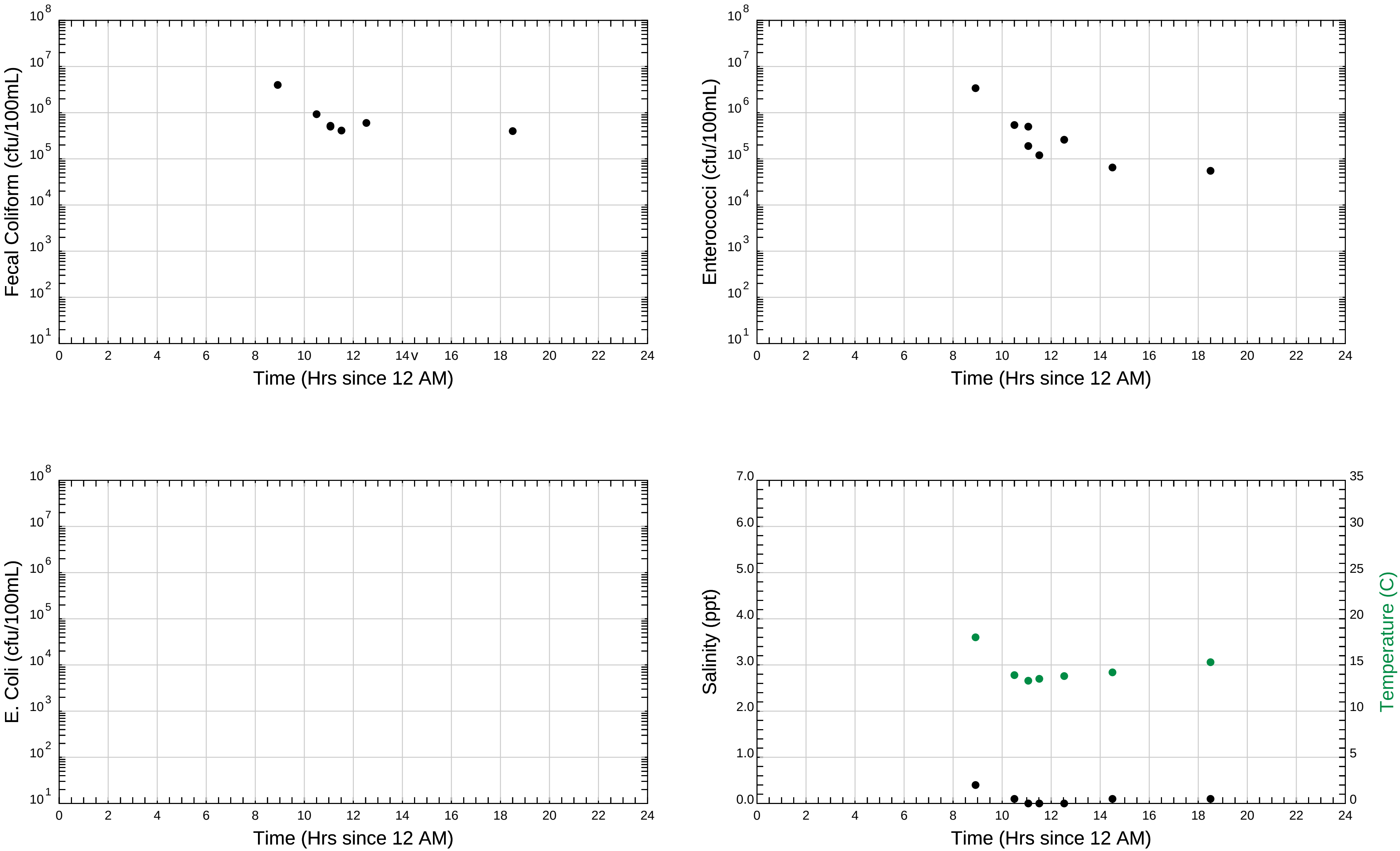






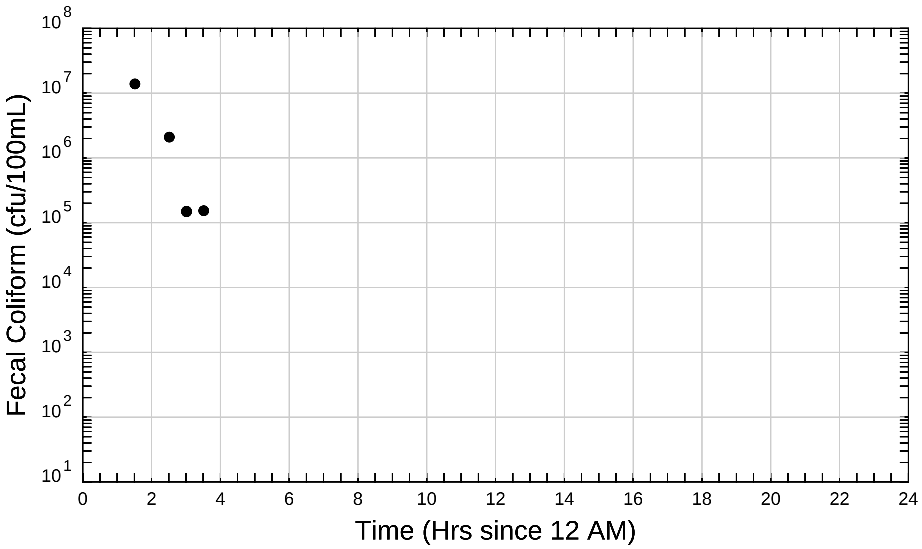
Wet-Weather Event 11. 29. 2016.

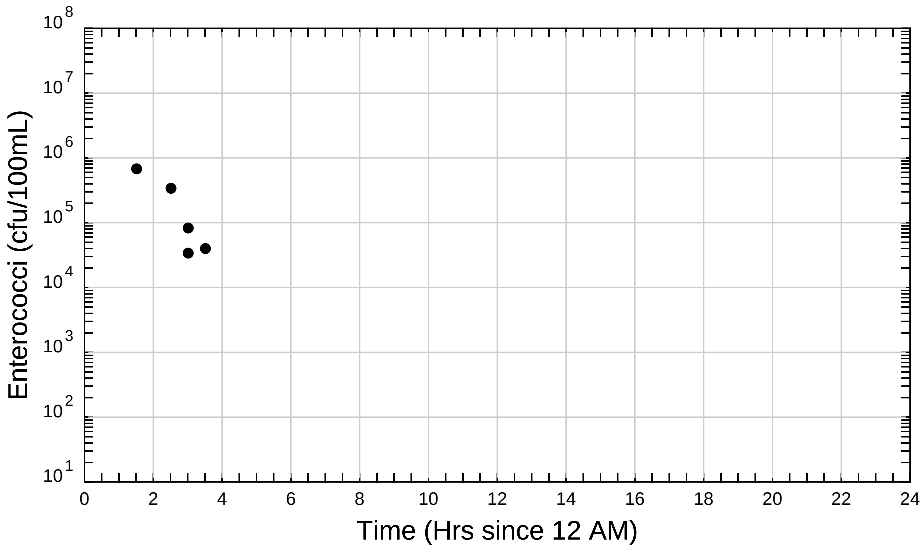
Station: C1-KEA-07A

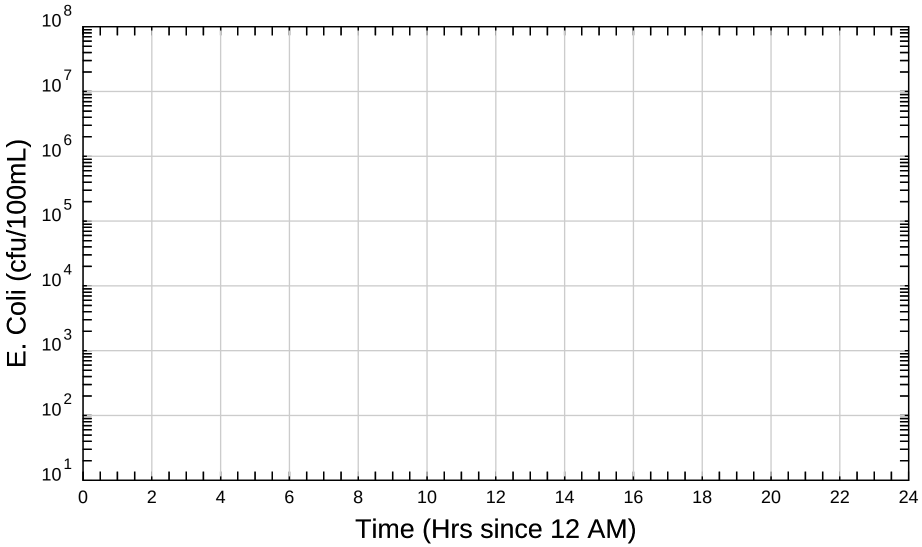


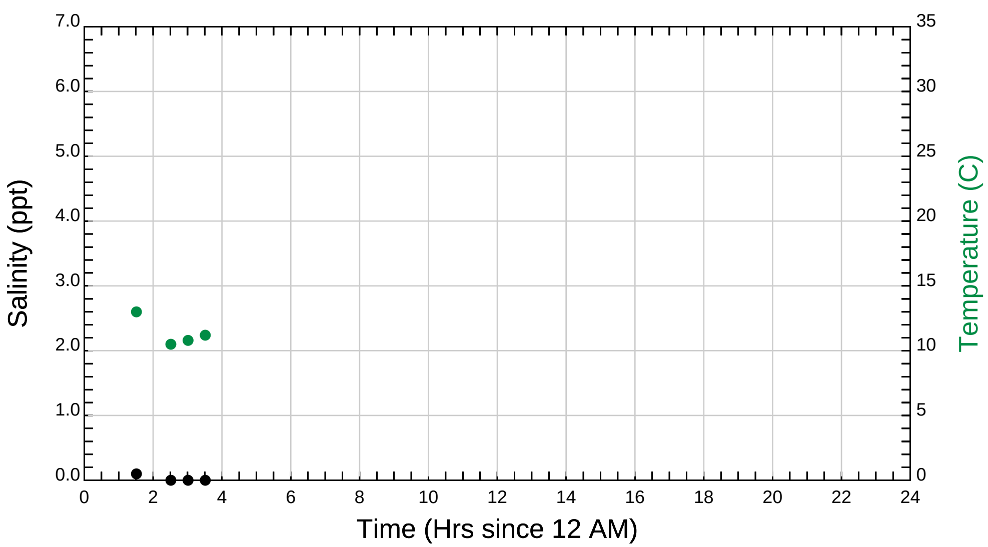
Wet-Weather Event 4. 4.2017.

Station: C1-KEA-07A



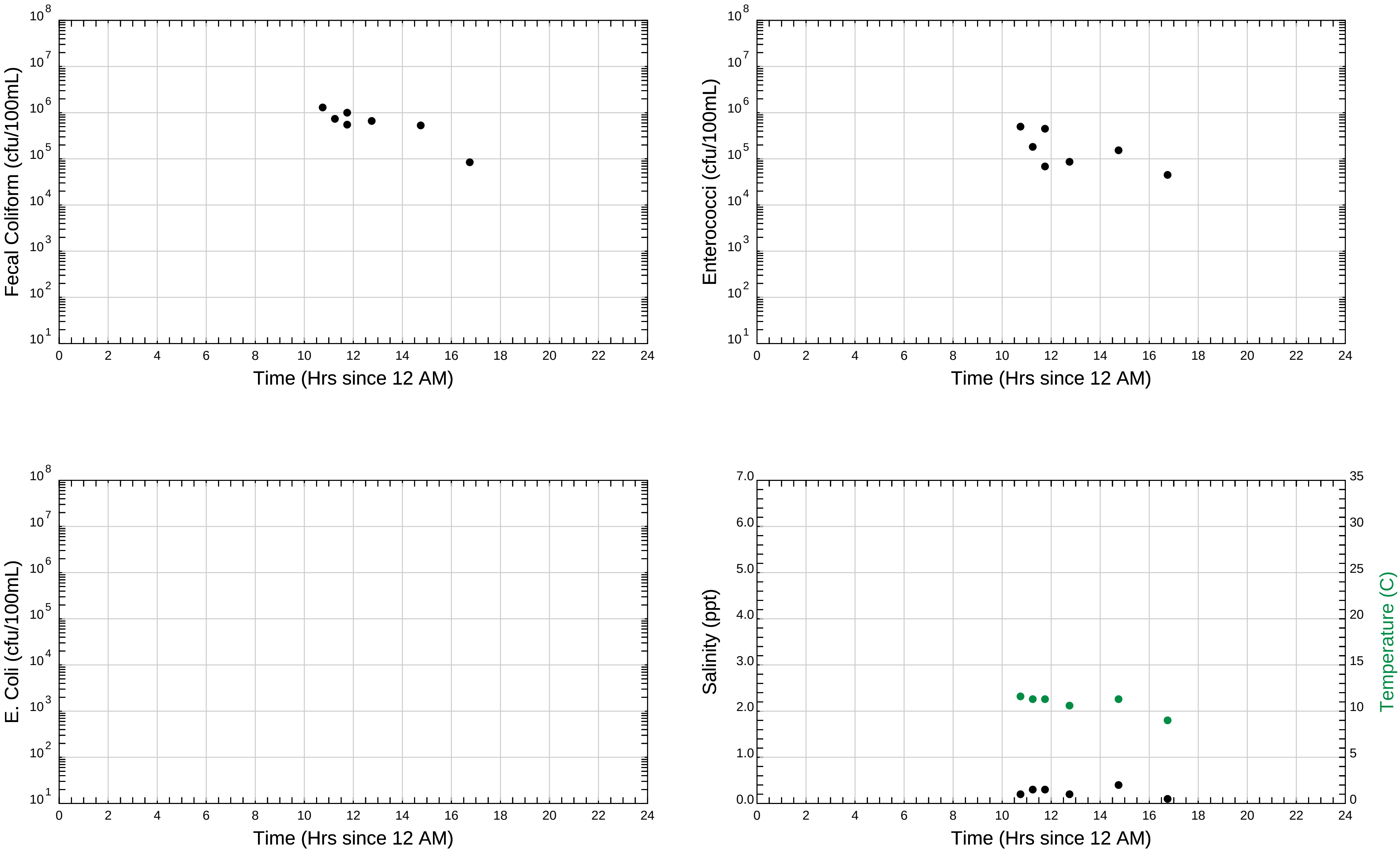






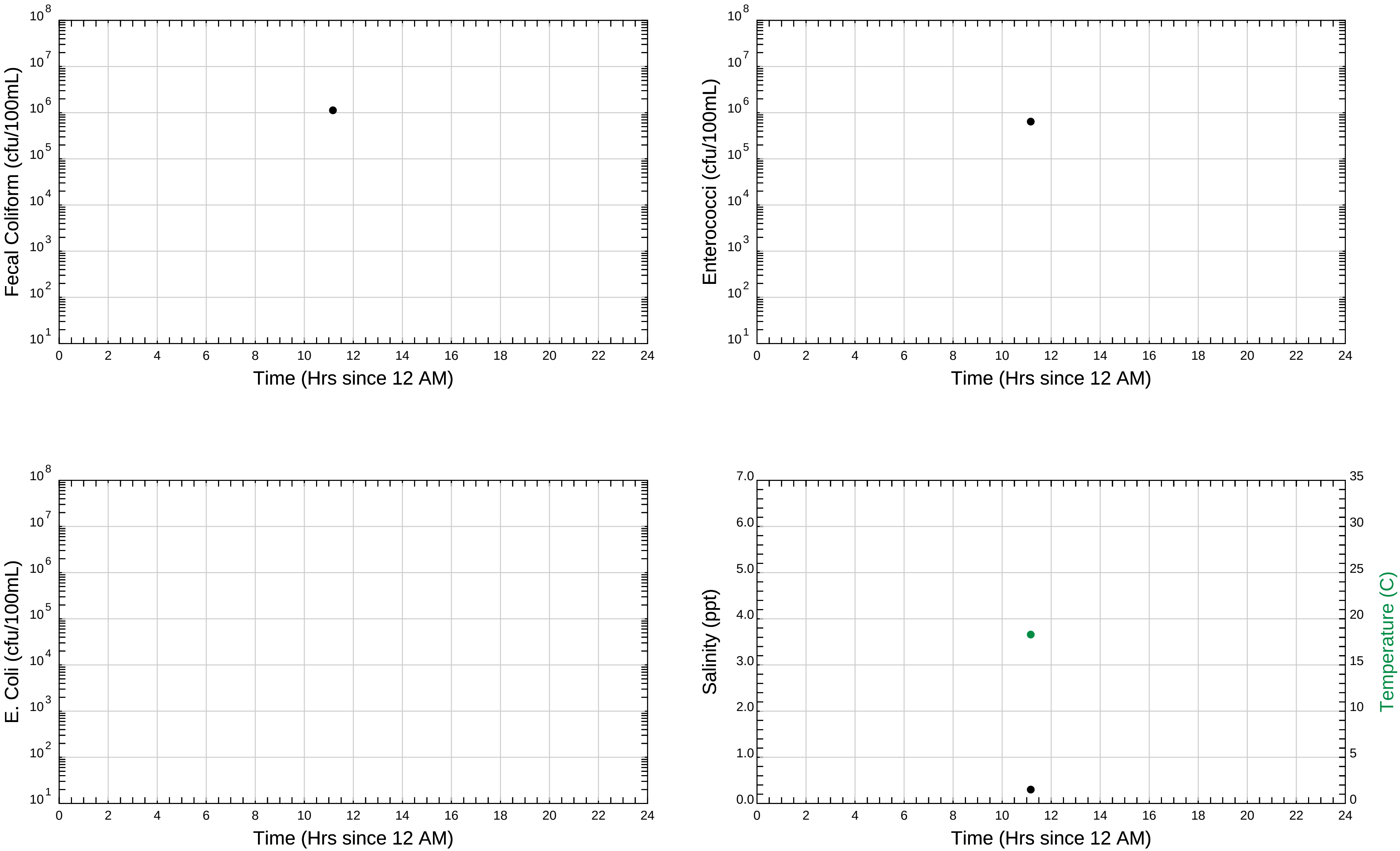
Wet-Weather Event 4. 6.2017.

Station: C1-NWK-14A



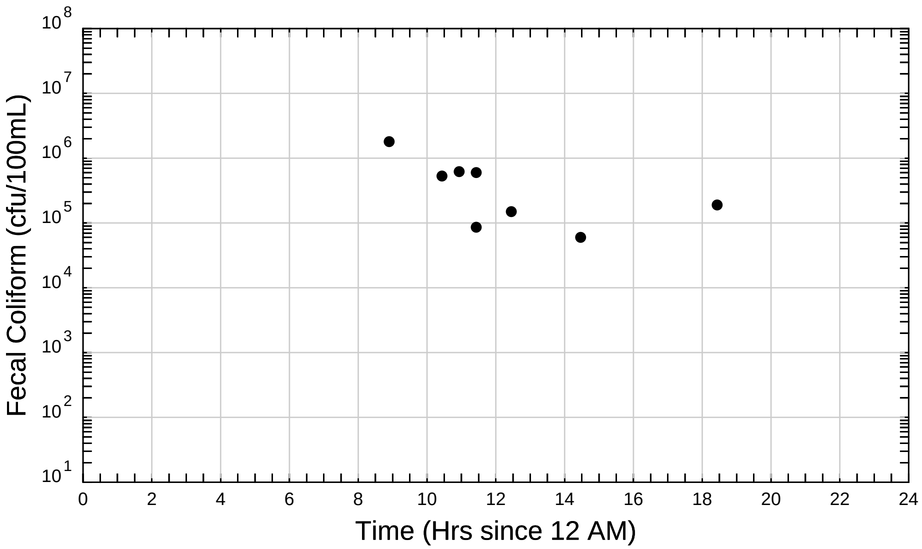
Wet-Weather Event 10. 27. 2016.

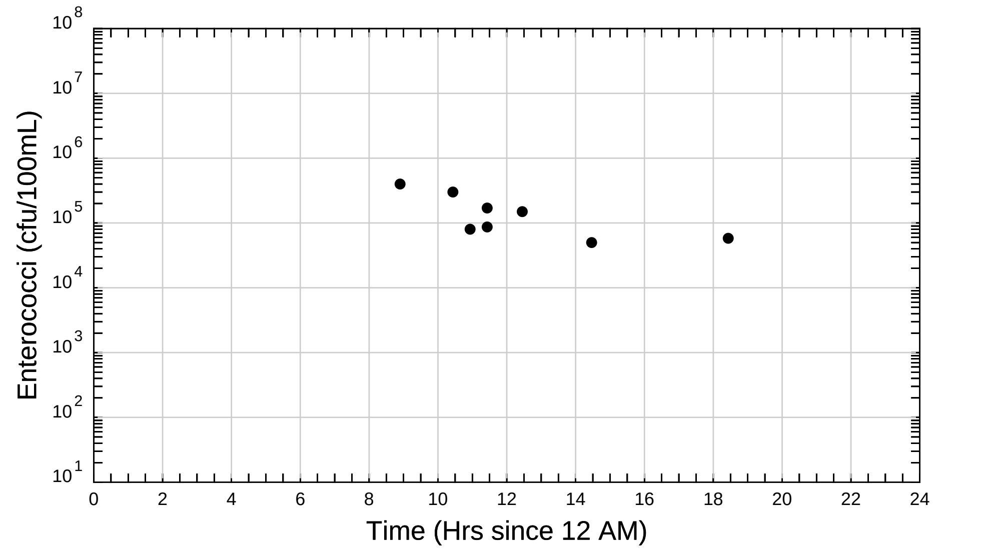
Station: C1-NWK-25A

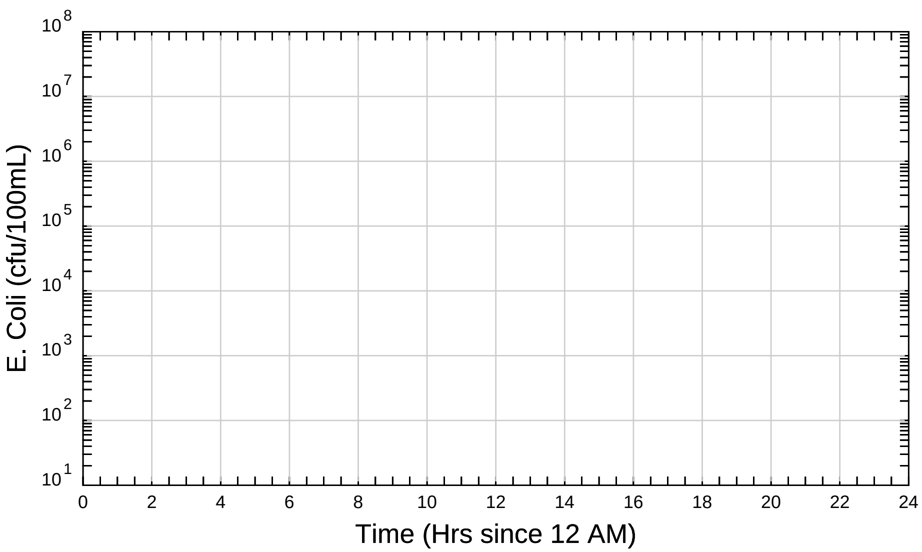


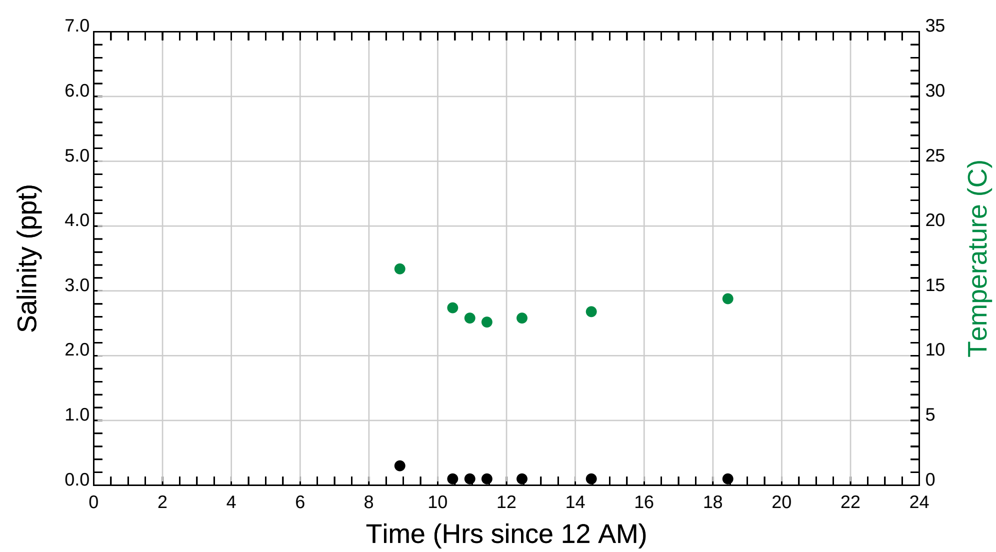
Wet-Weather Event 11. 29.2016.

Station: C1-NWK-25A



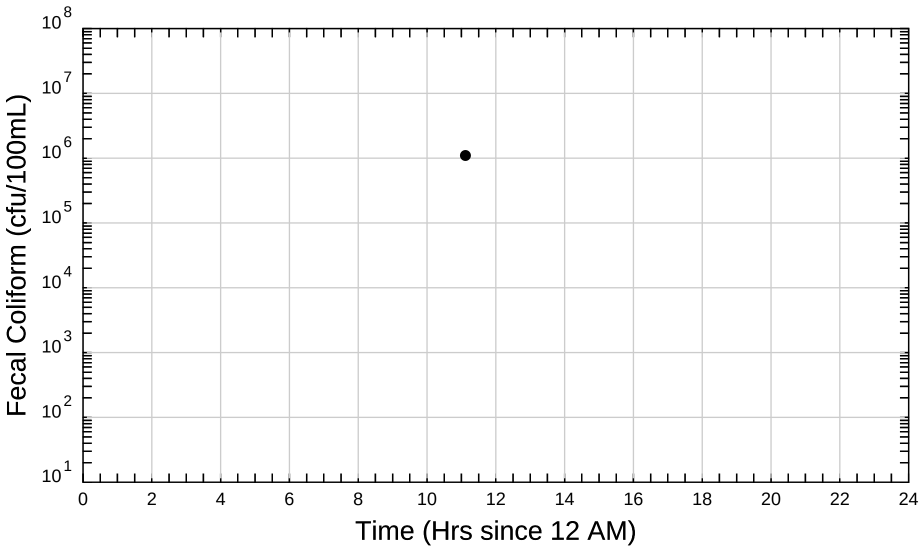


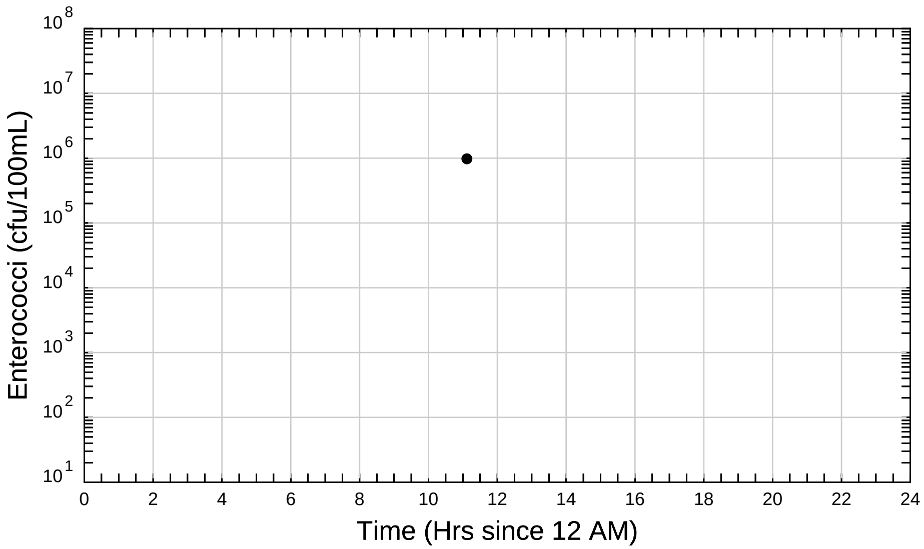


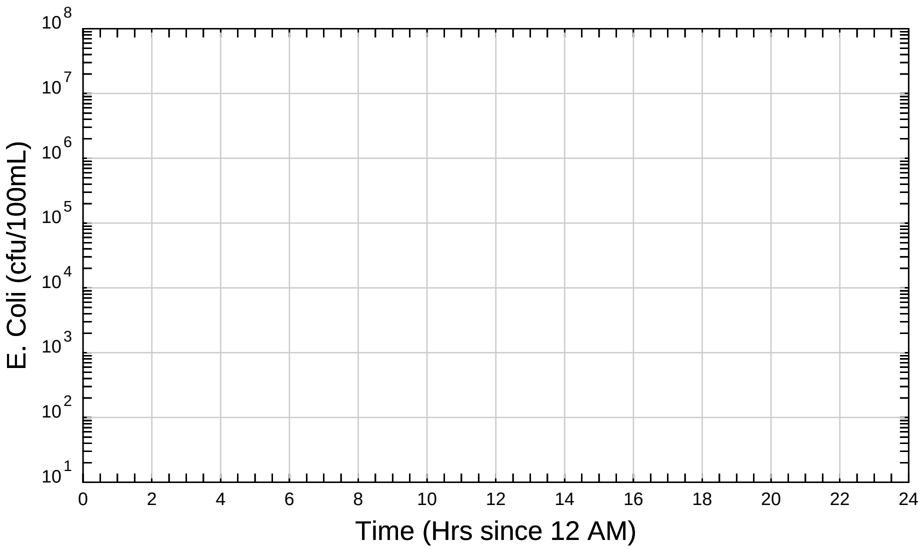


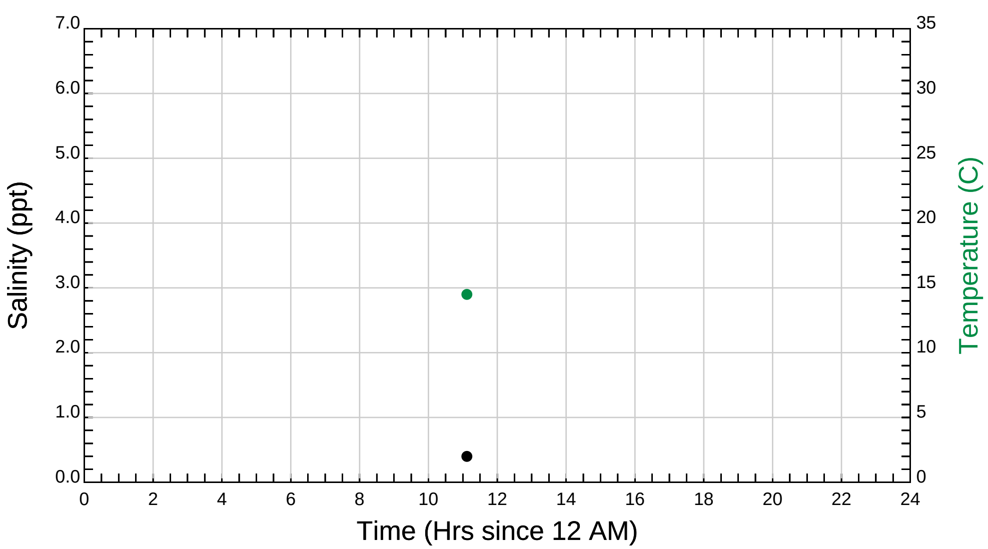
Wet-Weather Event 10. 27. 2016.

Station: C1-NWK-45A



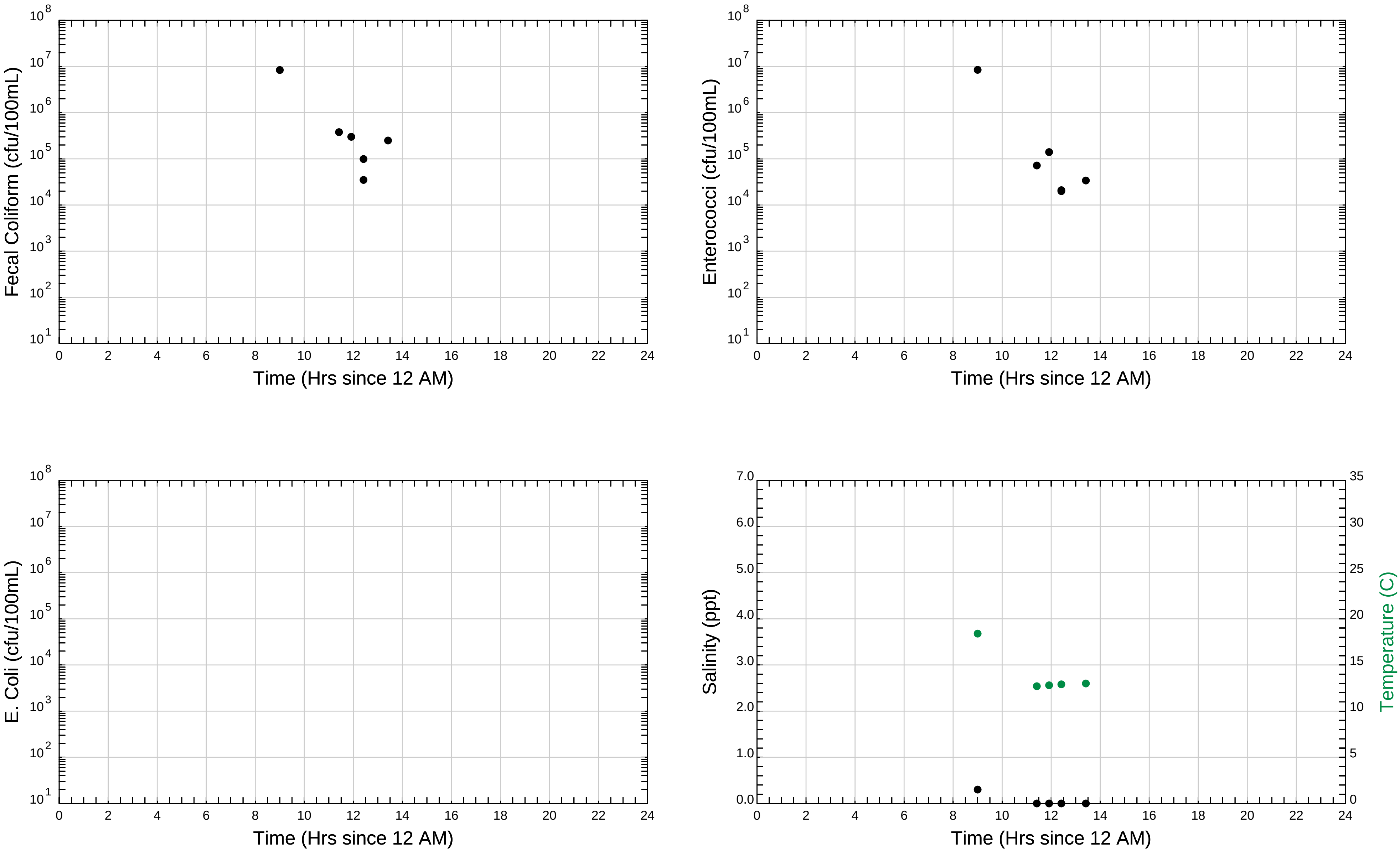






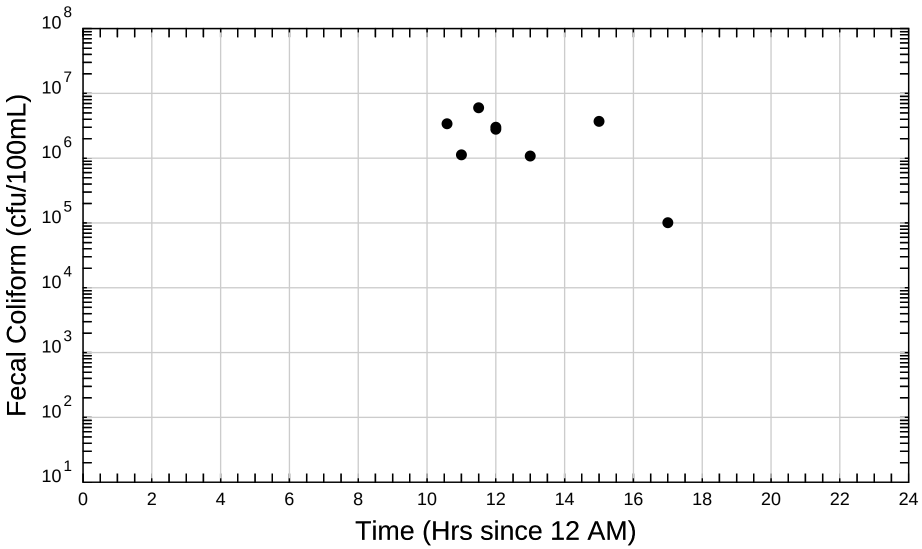
Wet-Weather Event 11. 29. 2016.

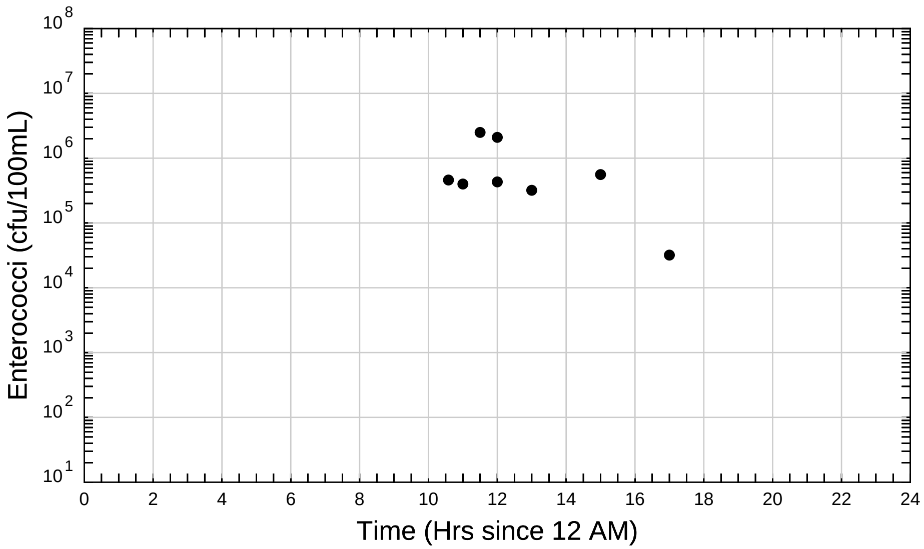
Station: C1-NWK-45A

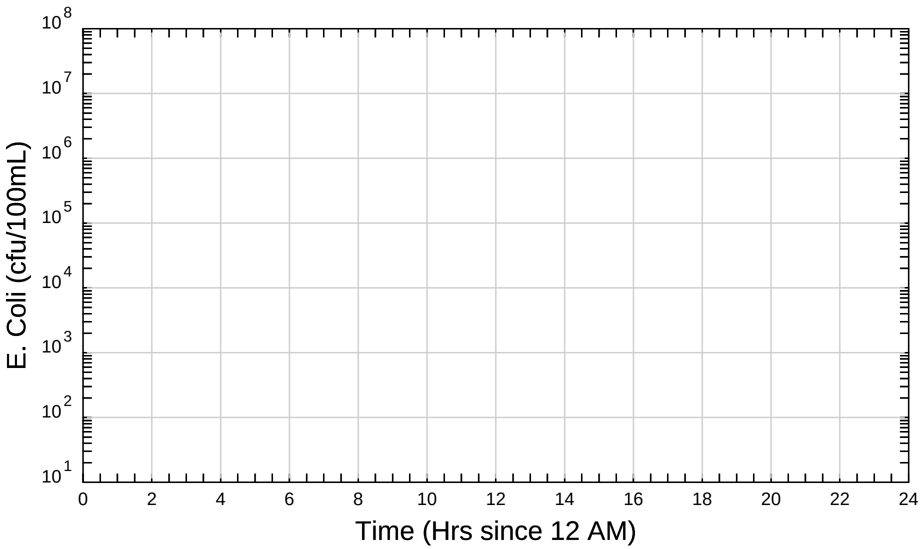


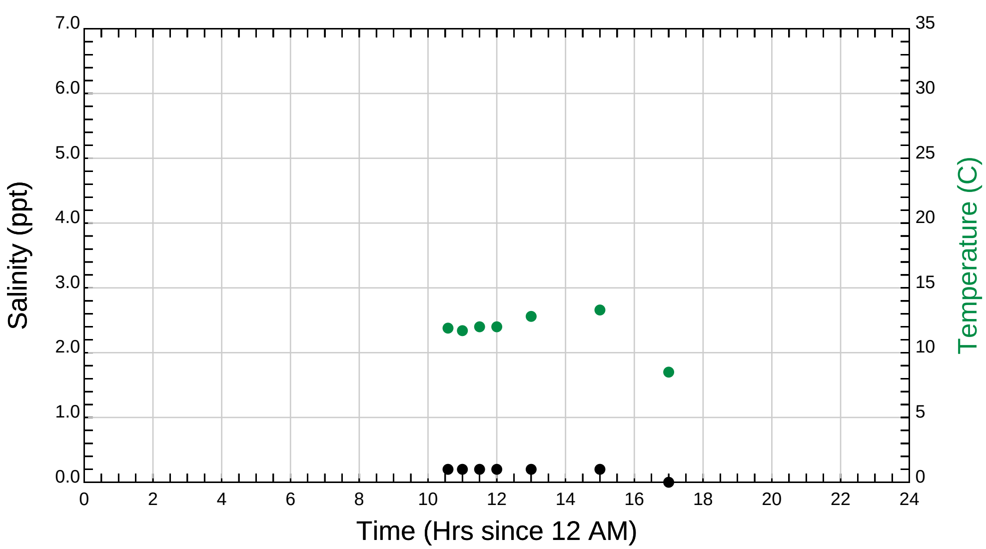
Wet-Weather Event 4. 6.2017.

Station: C1-NWK-45A



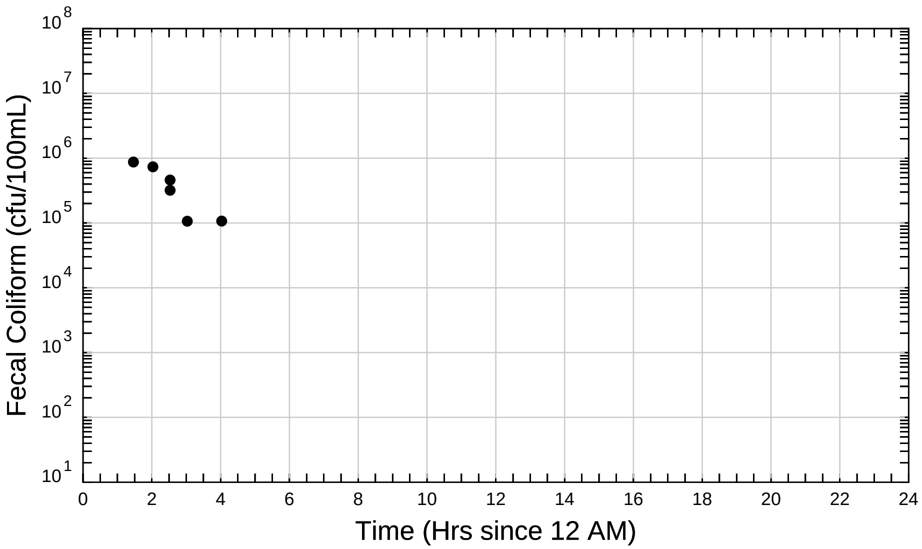


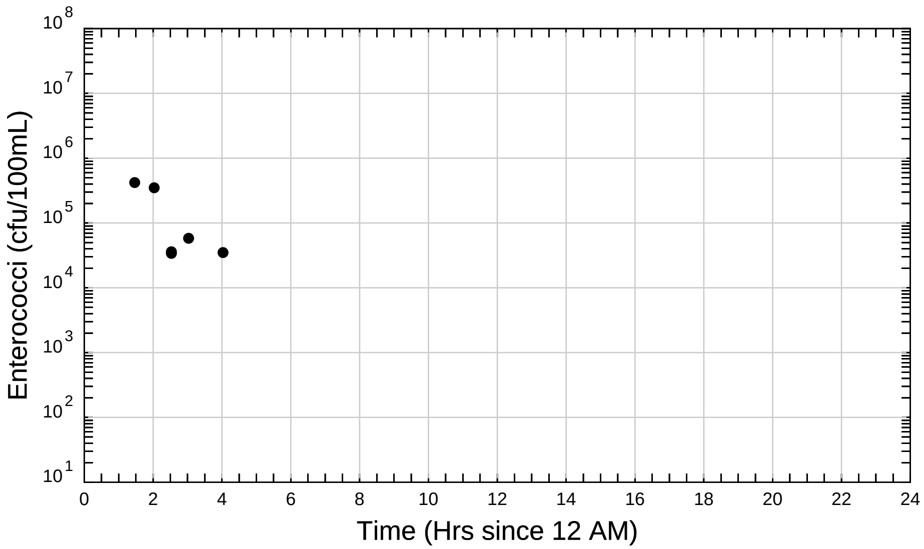


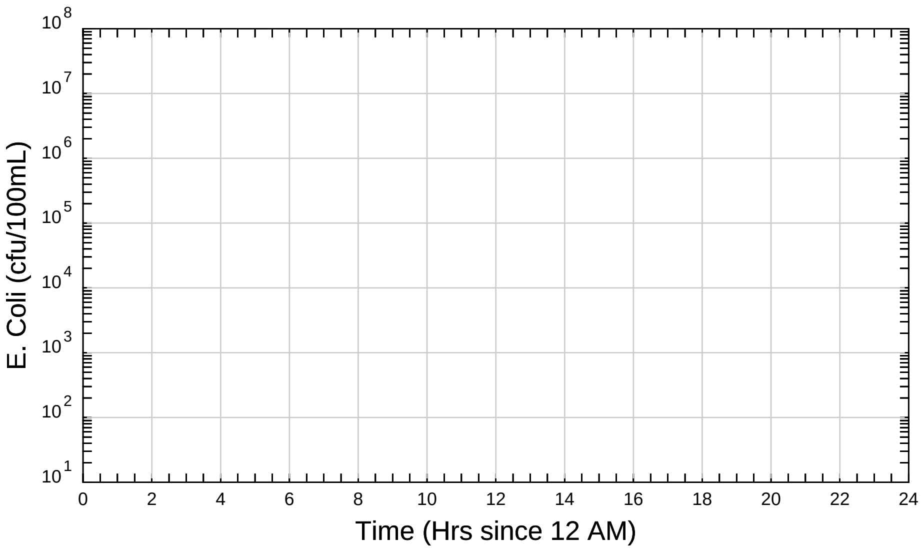


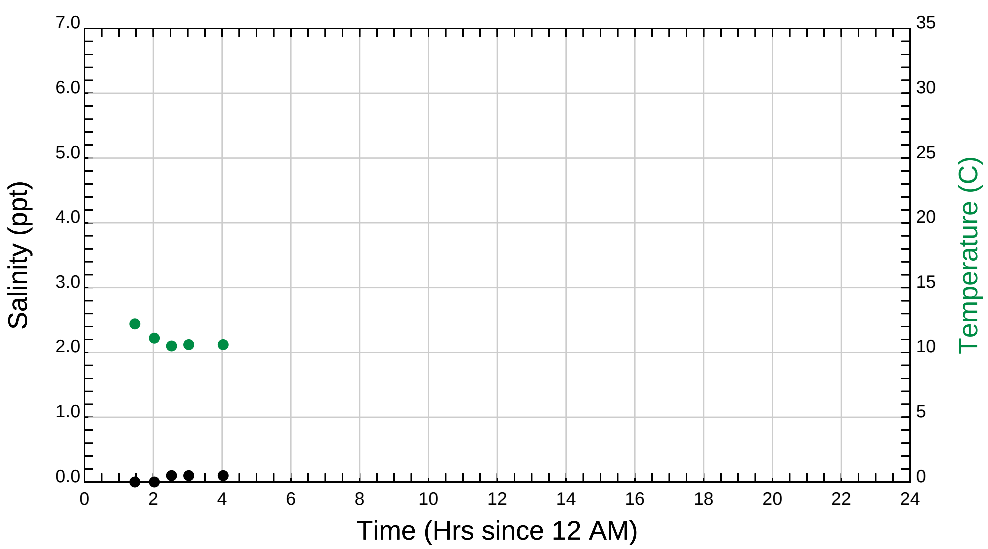
Wet-Weather Event 4. 4.2017.

Station: C1-NWK-91A



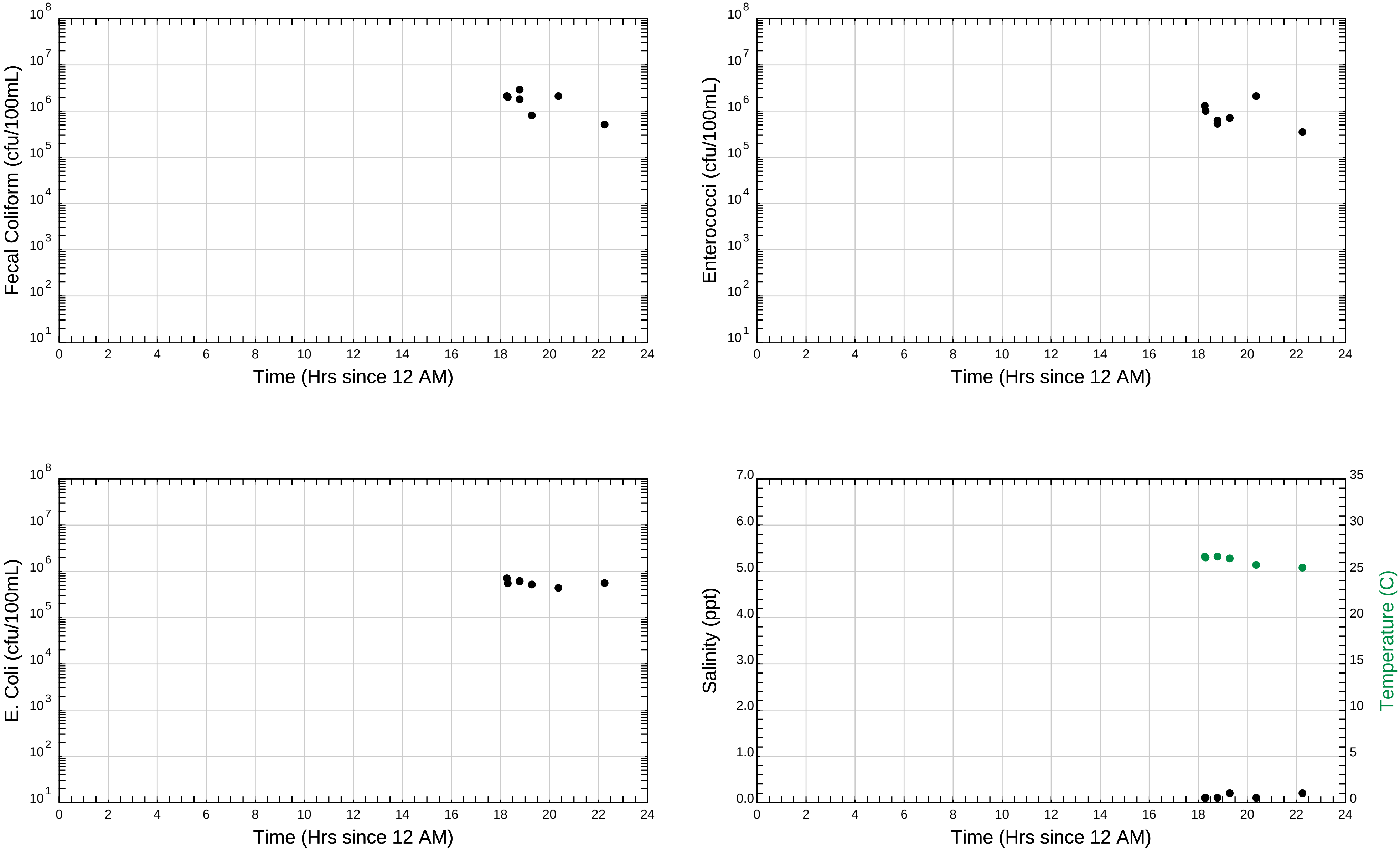






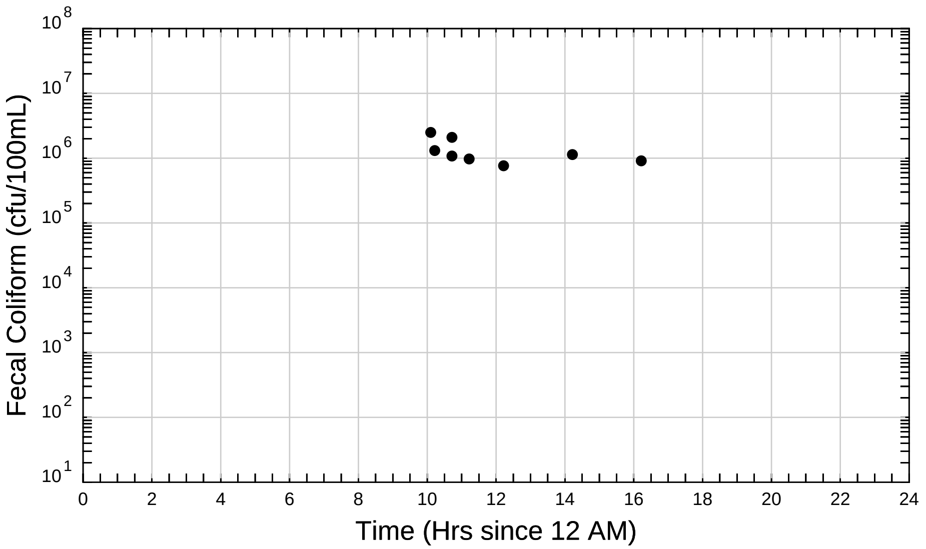
Wet-Weather Event 8. 21.2016.

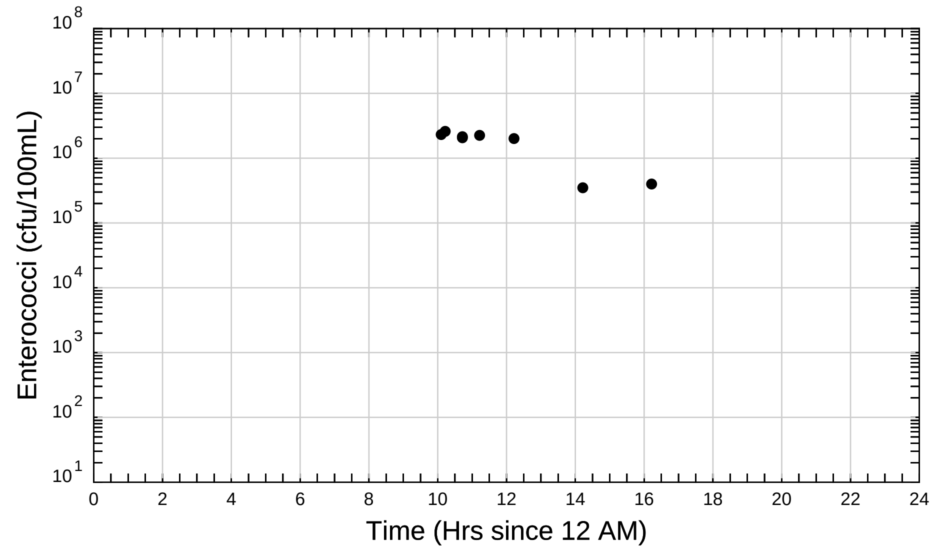
Station: C1-PAT-06A

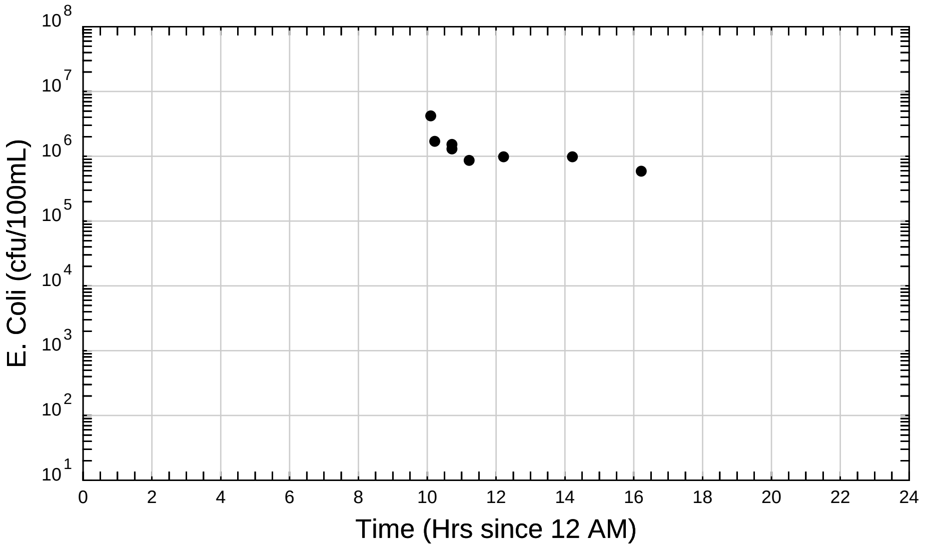


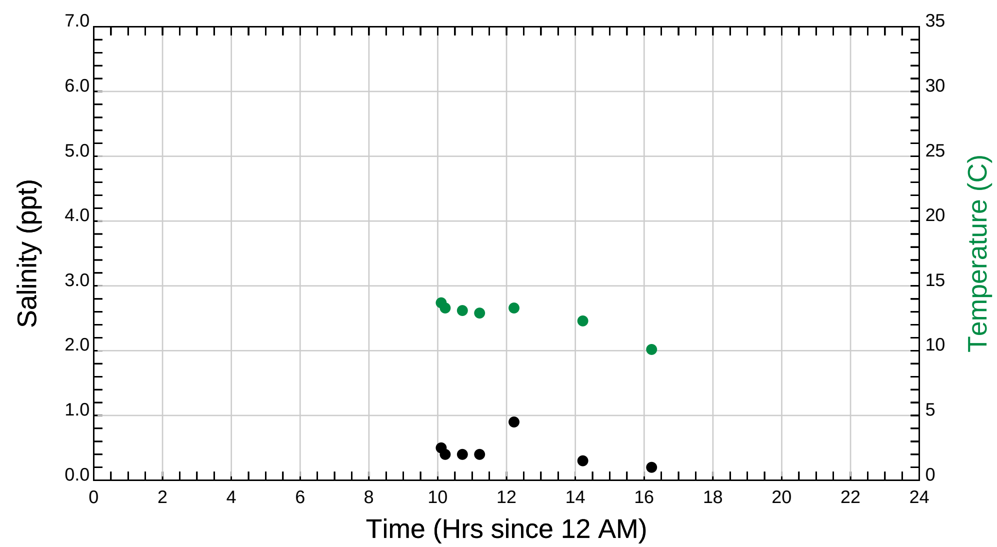
Wet-Weather Event 4. 6.2017.

Station: C1-PAT-06A



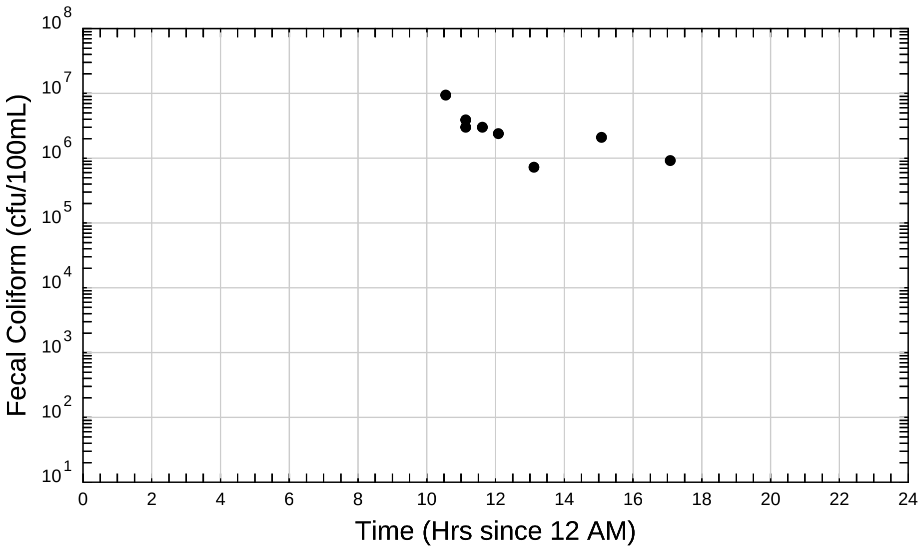


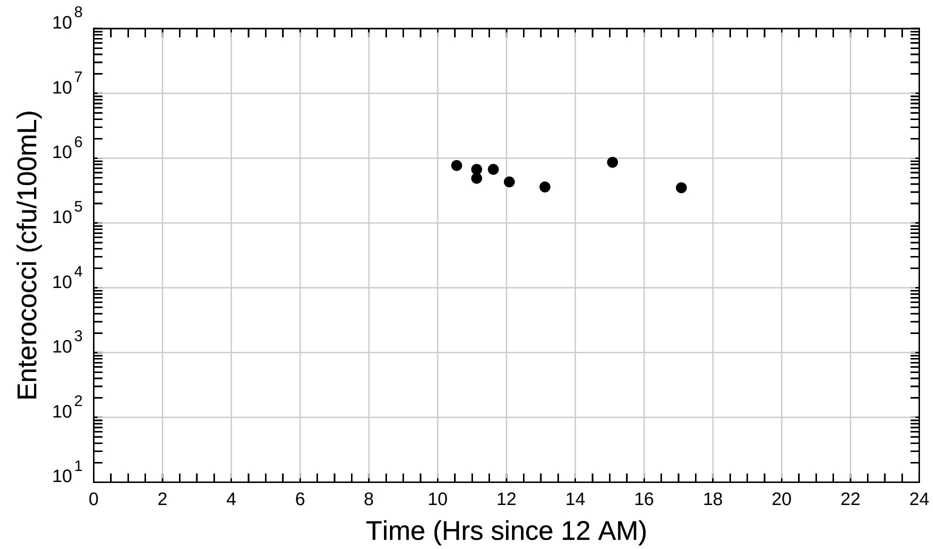


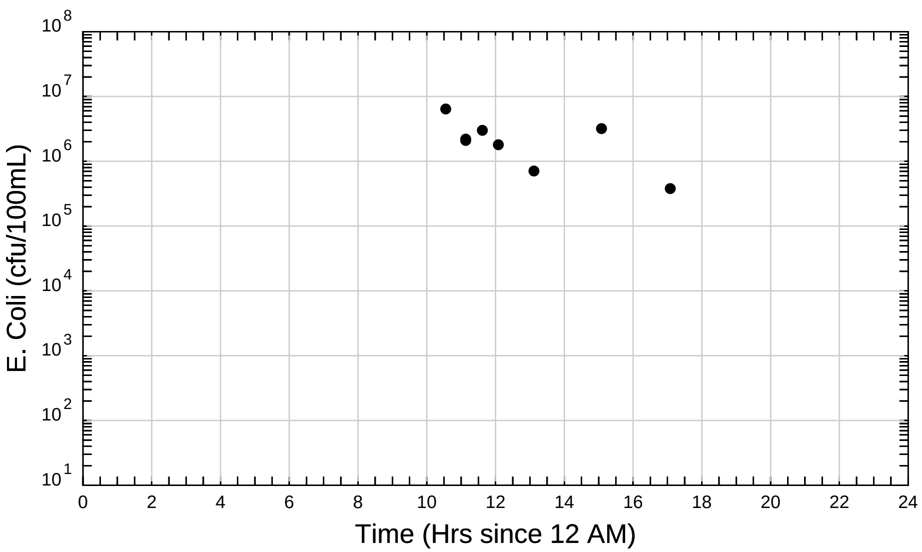


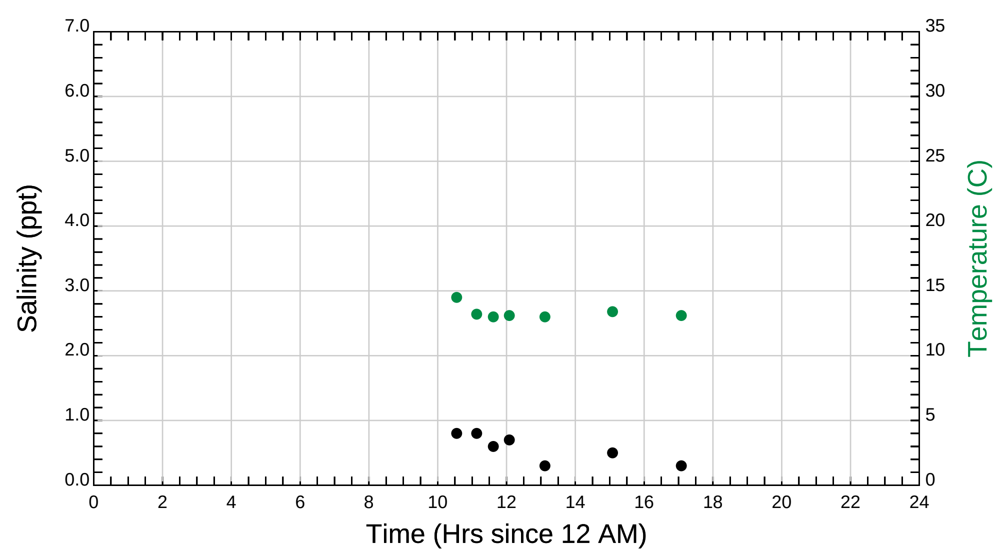
Wet-Weather Event 4. 6.2017.

Station: C1-PAT-27A



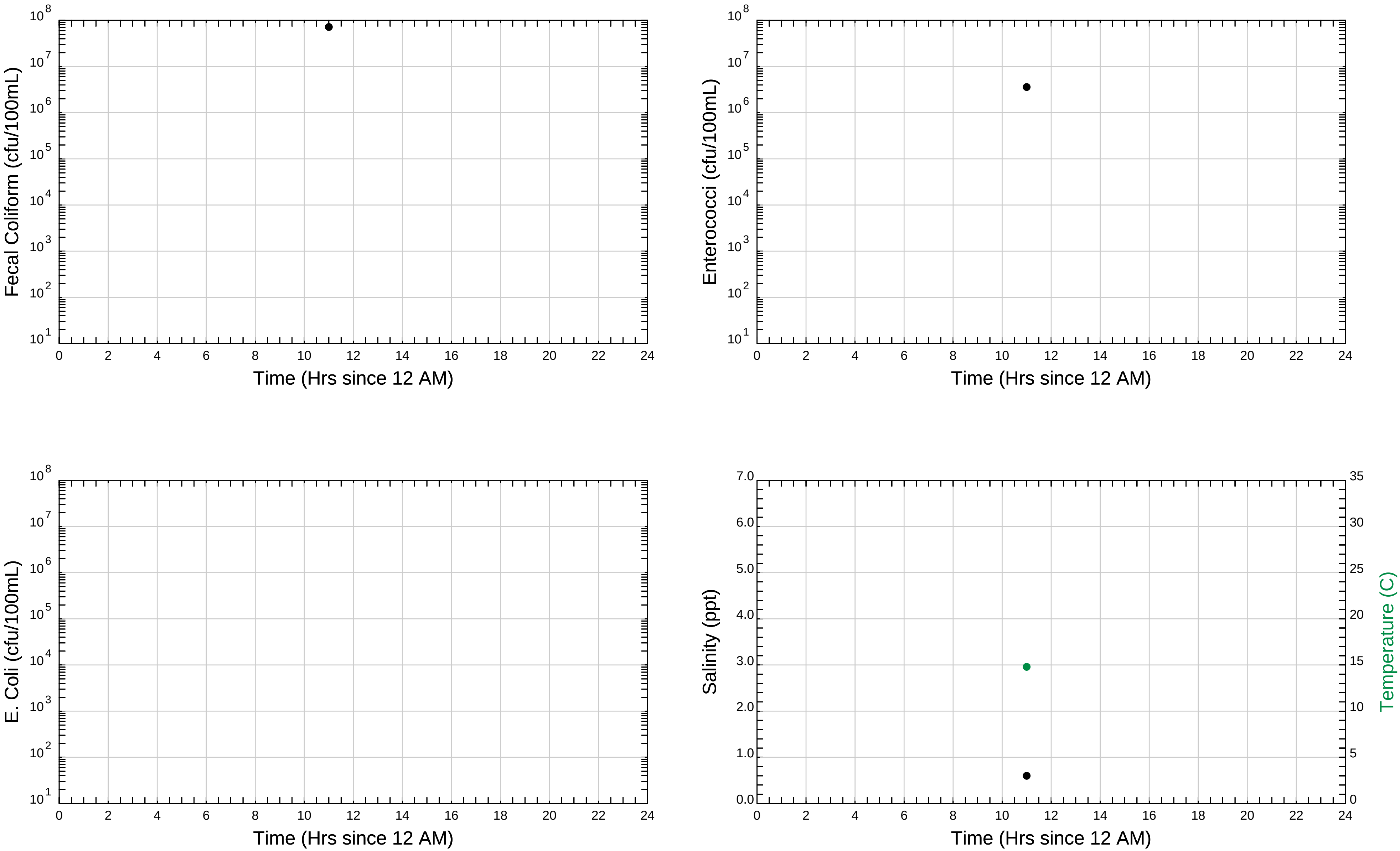






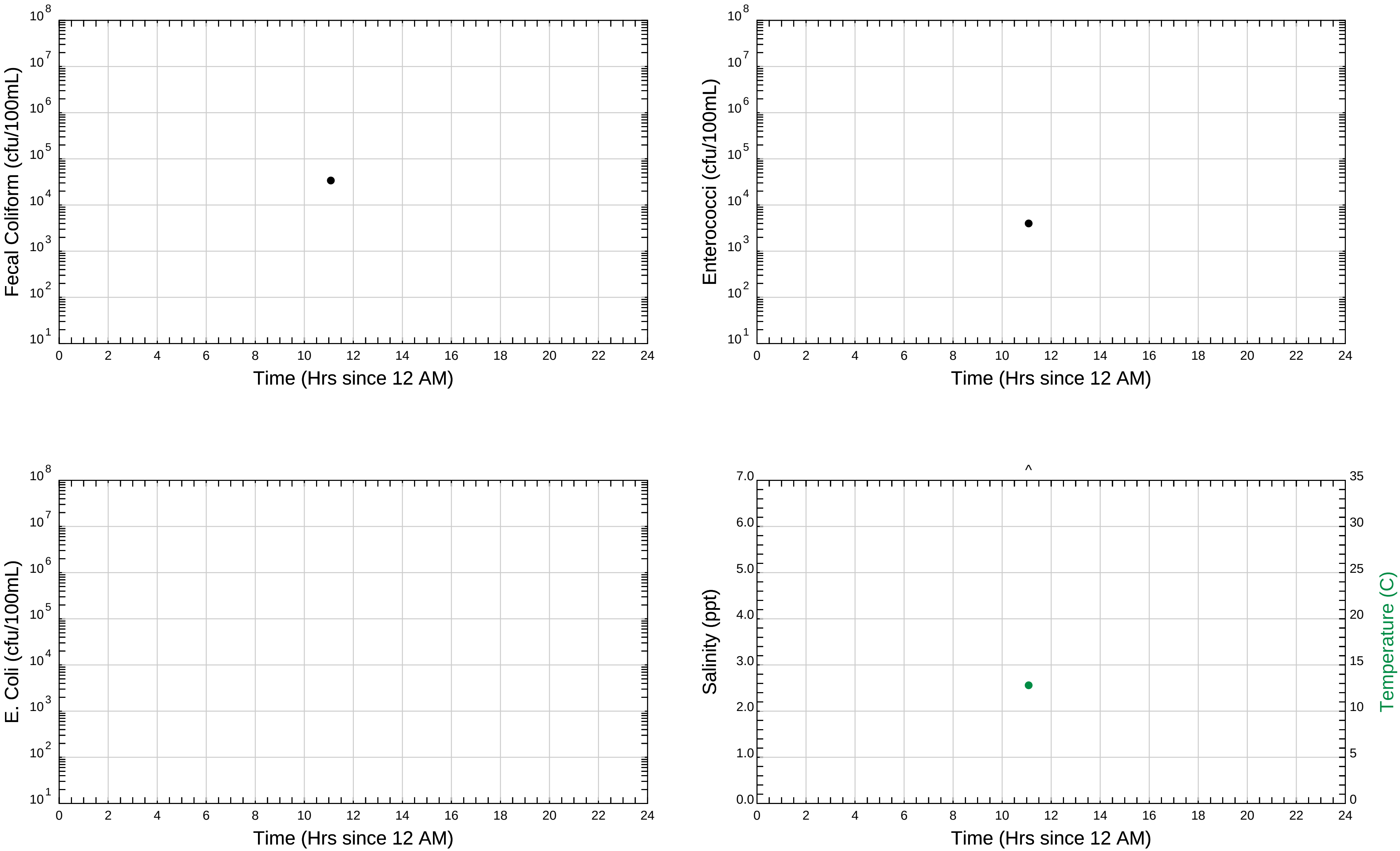
Wet-Weather Event 4. 25. 2017.

Station: C2-BAY-08A



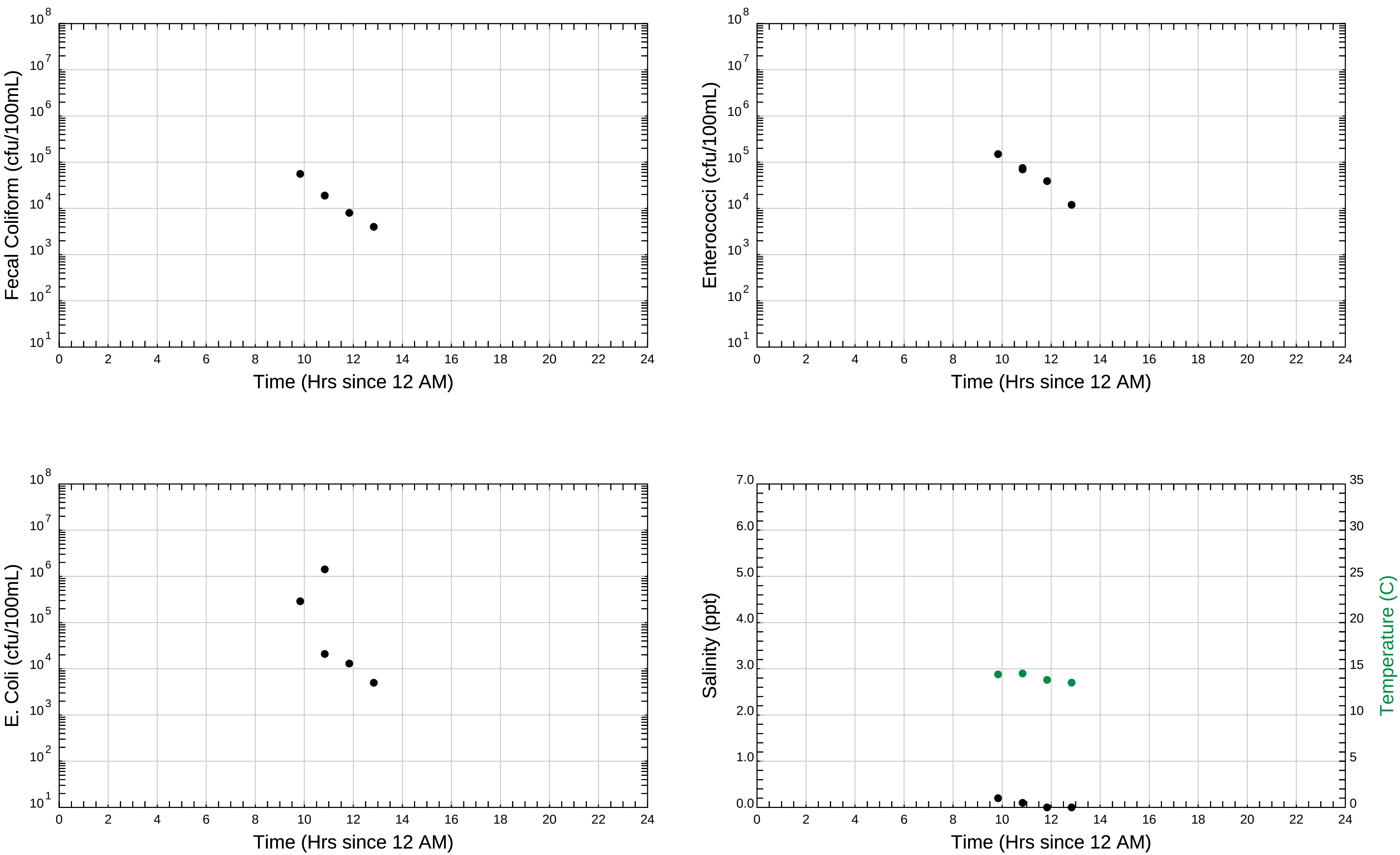
Wet-Weather Event 4. 25. 2017.

Station: C2-BAY-10A



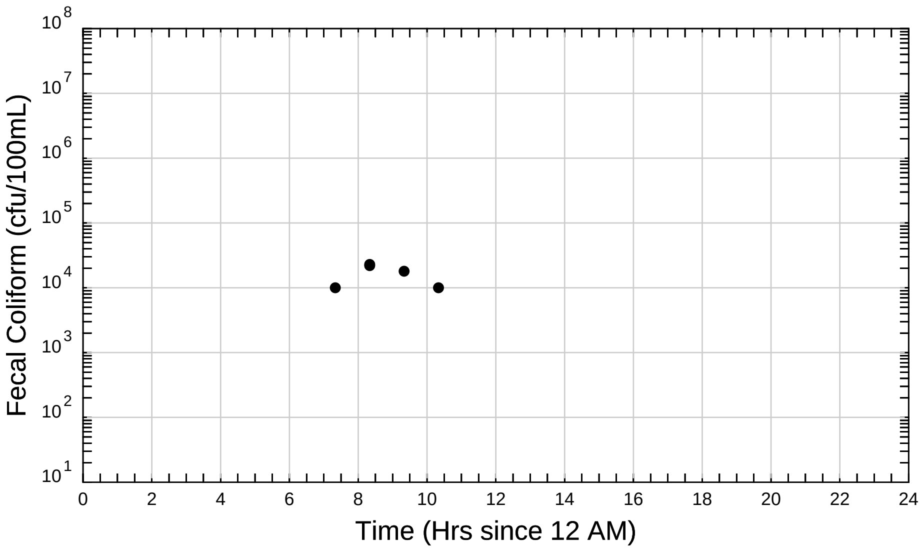
Wet-Weather Event 5. 5.2017.

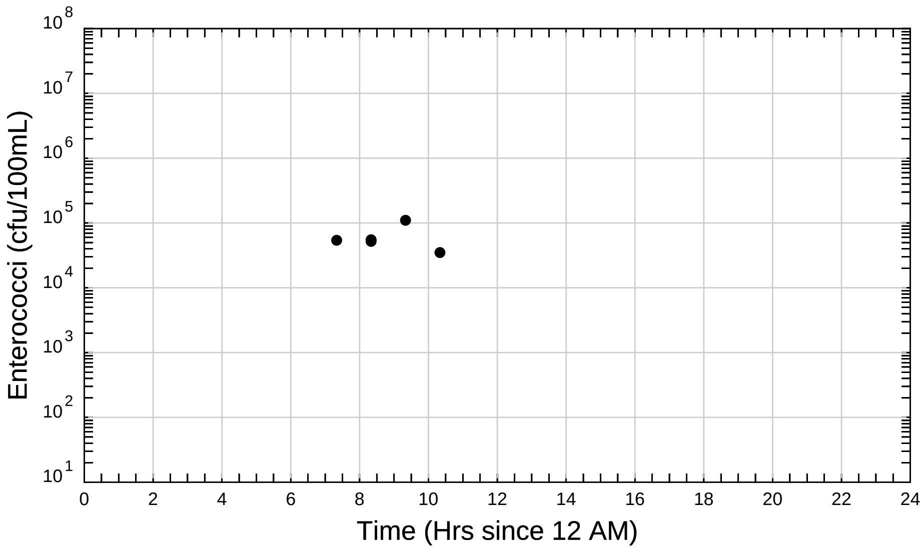
Station: S1-HAW-LR3

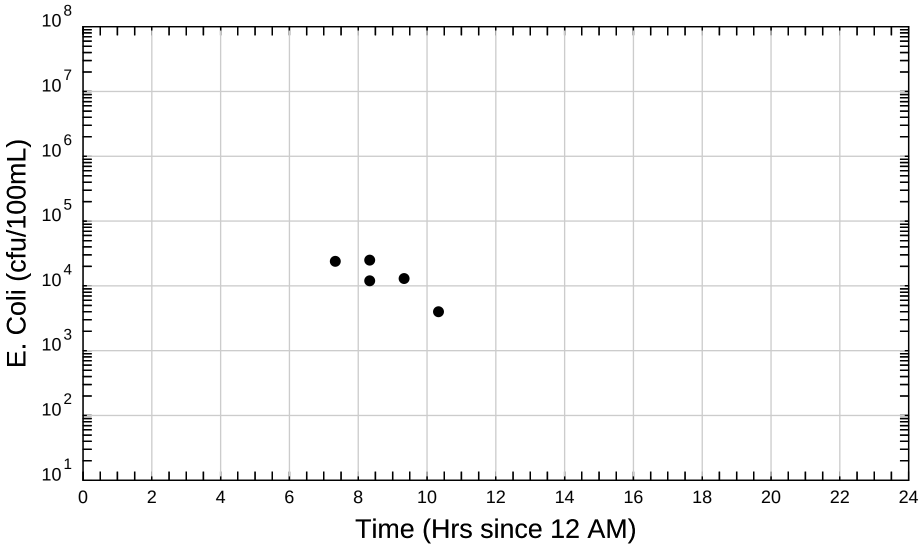


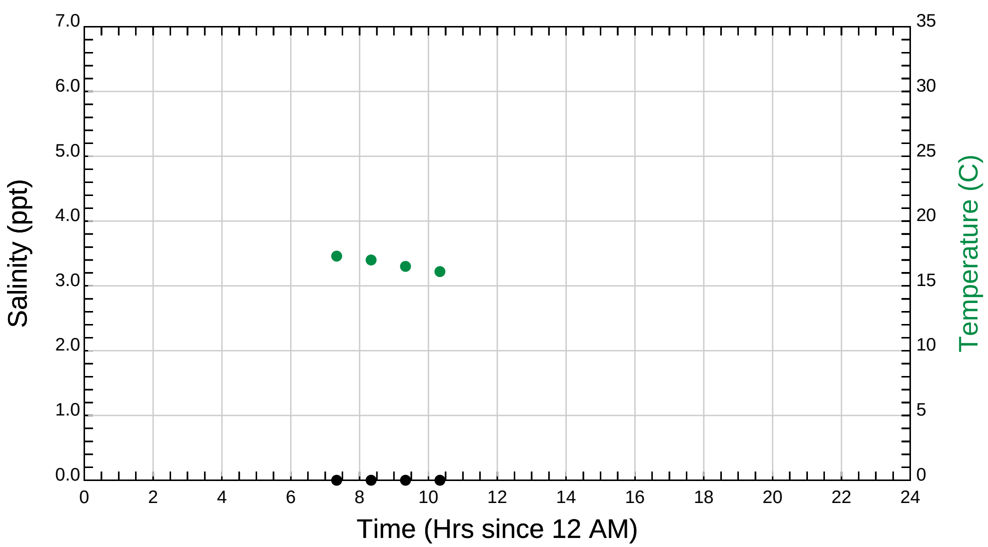
Wet-Weather Event 5. 25. 2017.

Station: S1-HAW-LR3



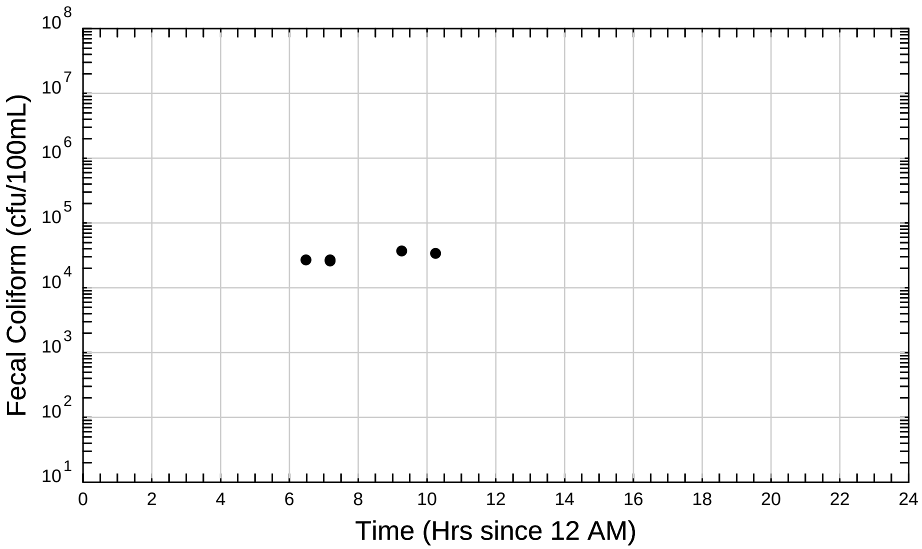


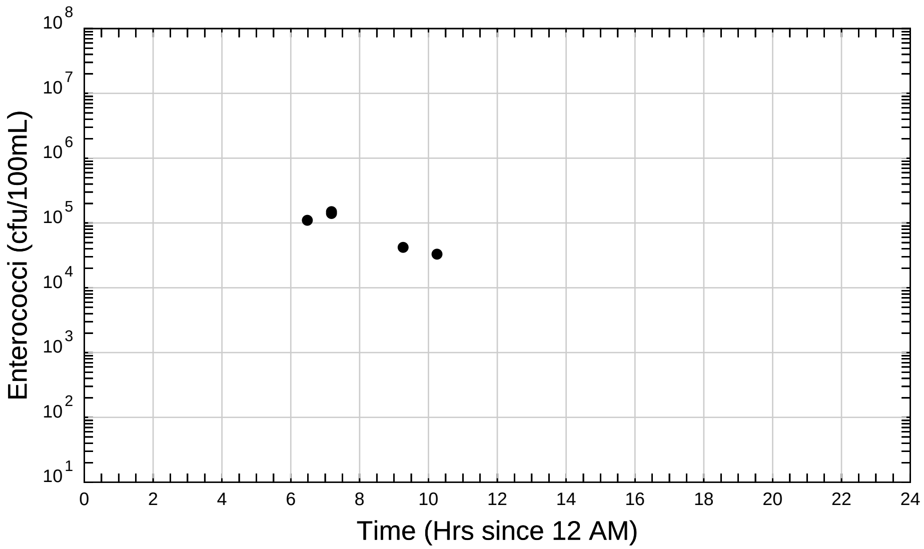


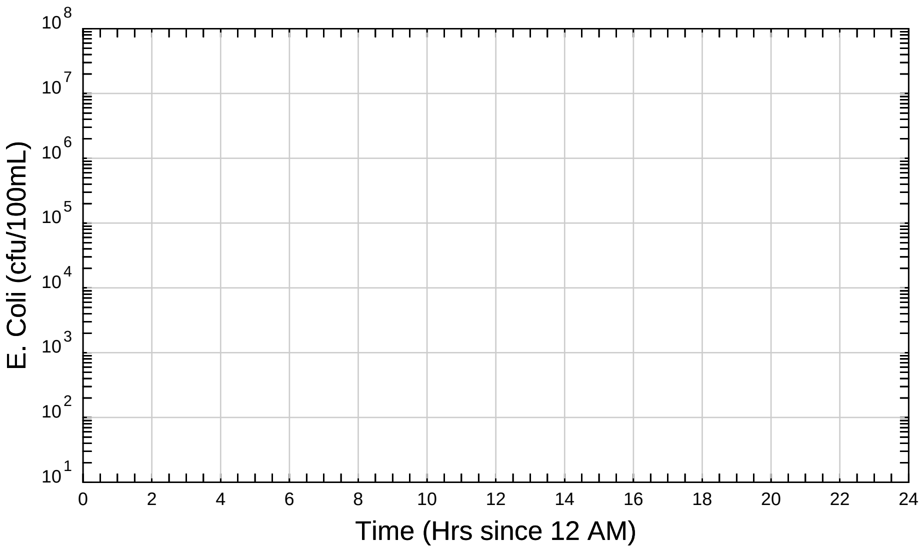


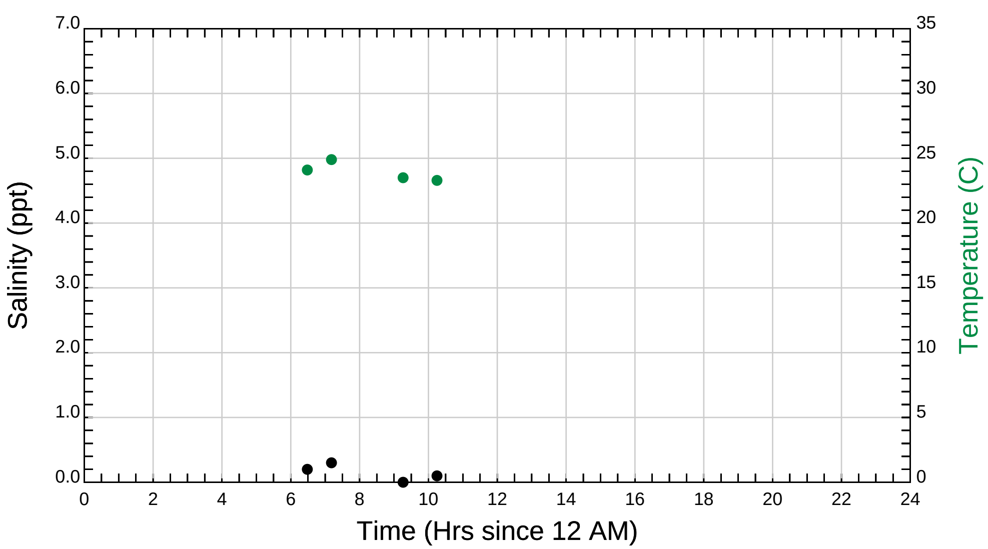
Wet-Weather Event 9. 19. 2016.

Station: S1-NWK-CI2



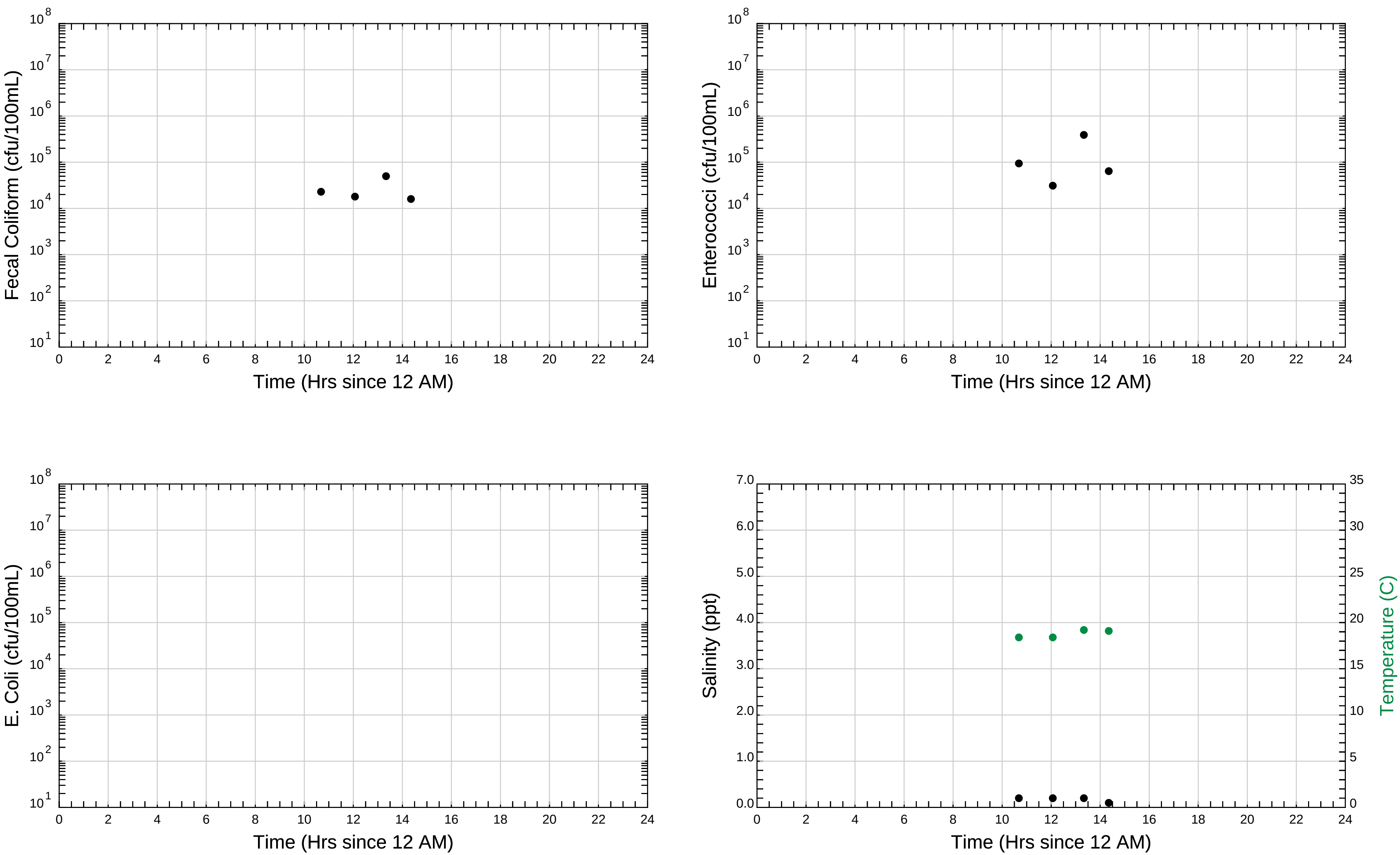






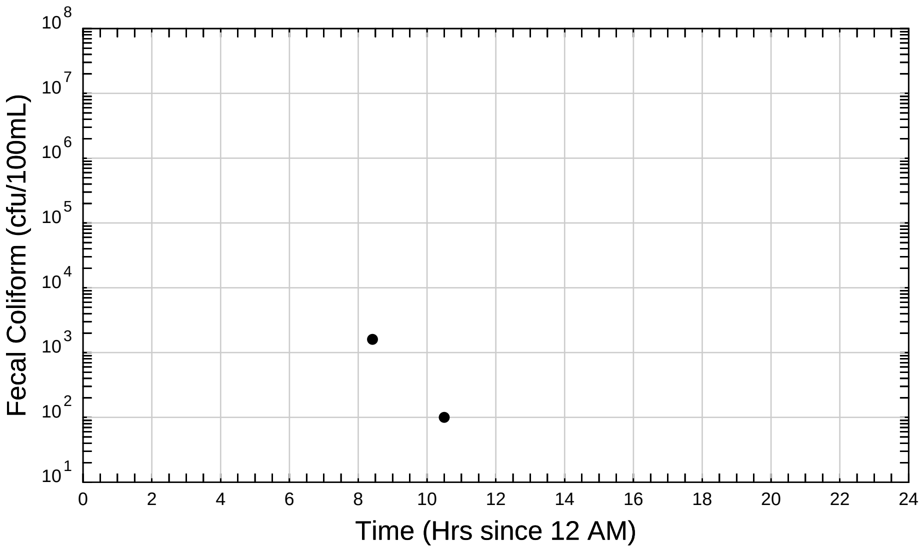
Wet-Weather Event 9. 30. 2016.

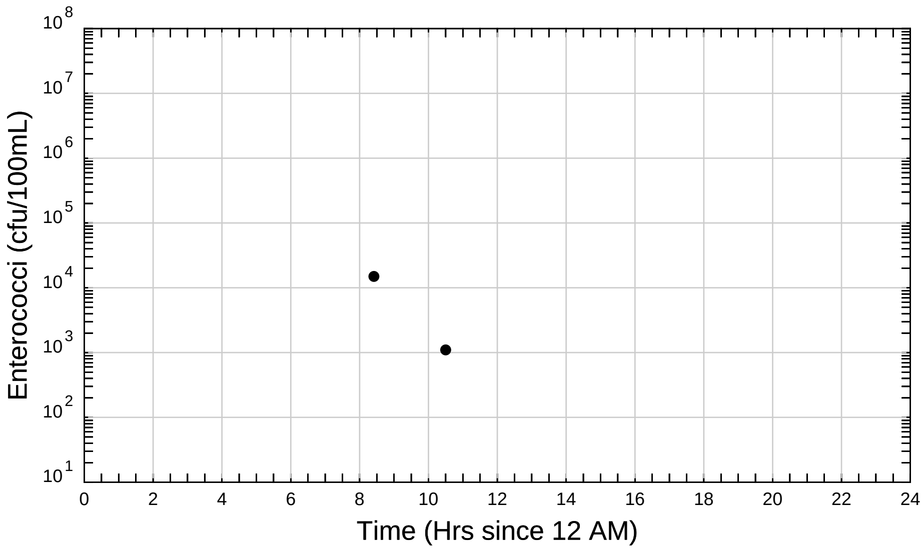
Station: S1-NWK-CI2

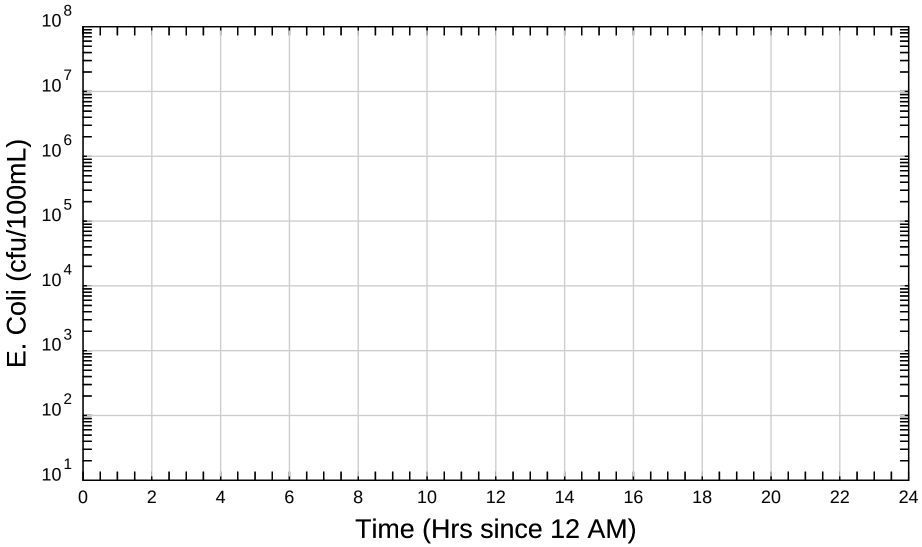


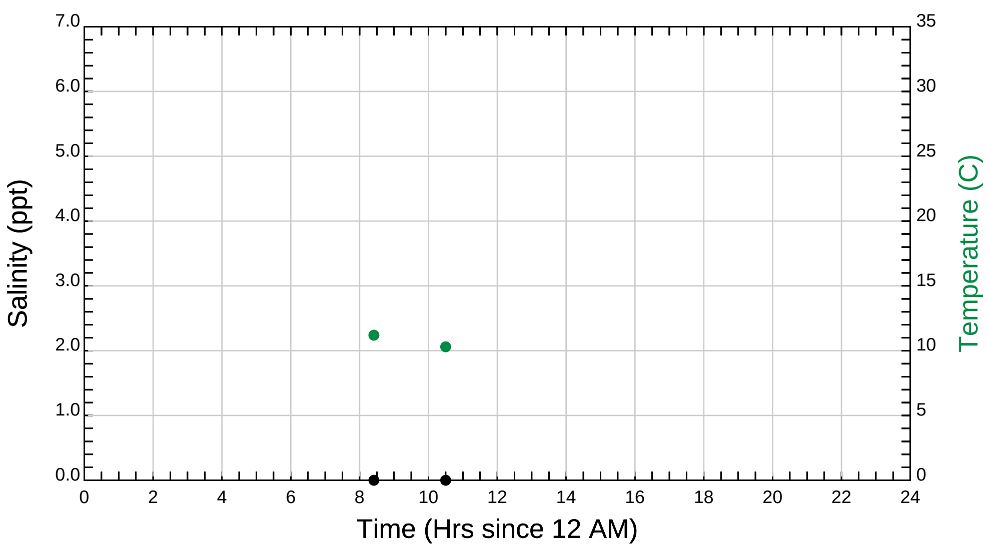
Wet-Weather Event 11.15.2016.

Station: S1-NWK-CI2



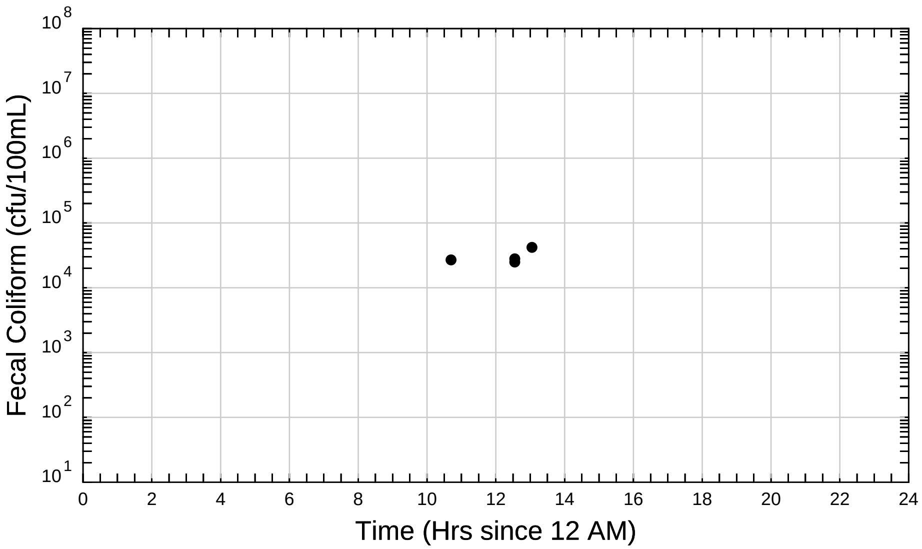


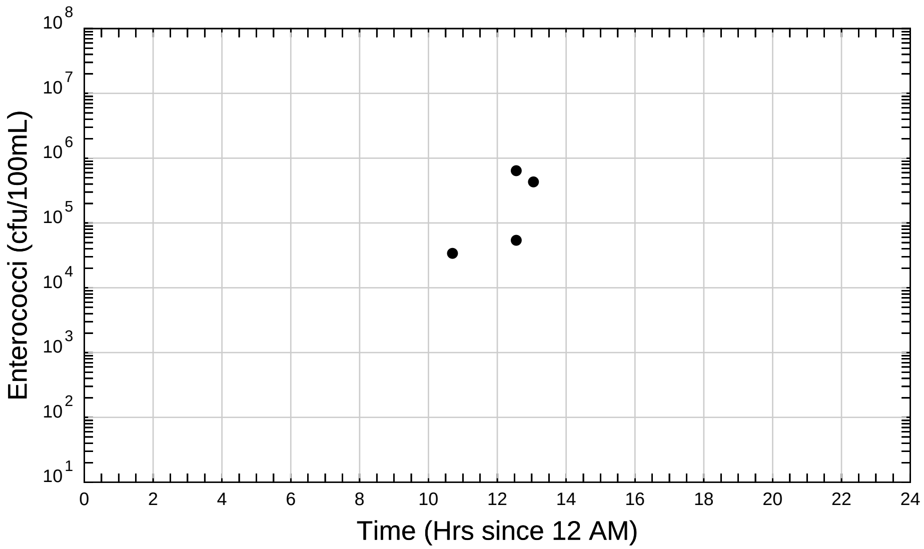


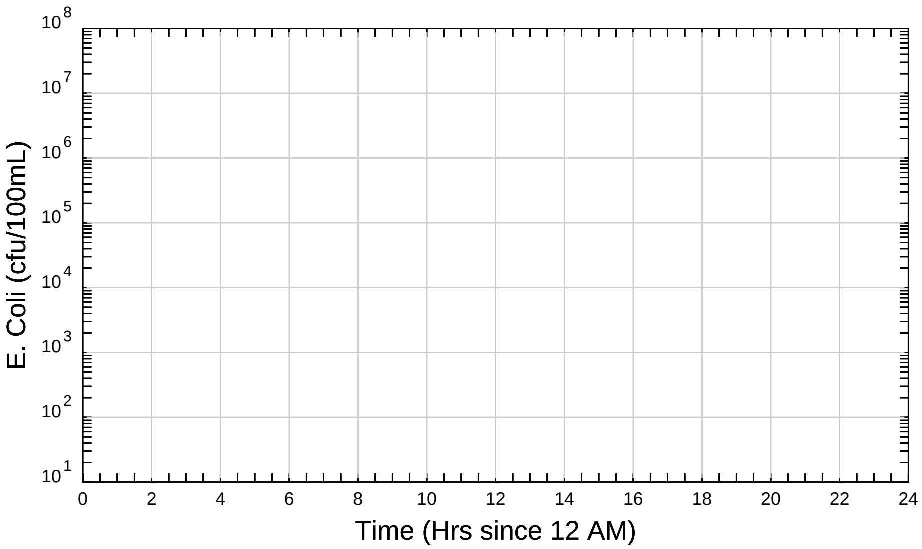


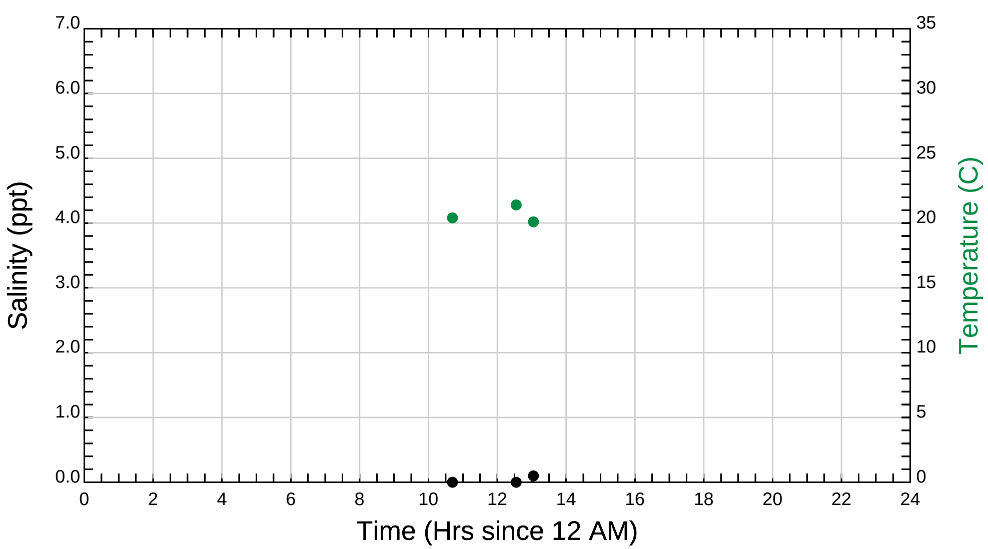
Wet-Weather Event 10. 21.2016.

Station: S1-NWK-HR1



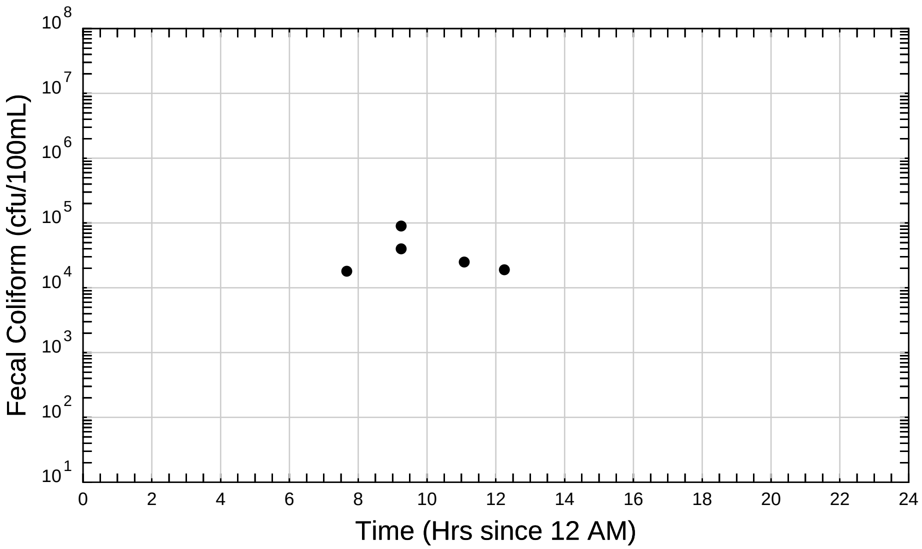


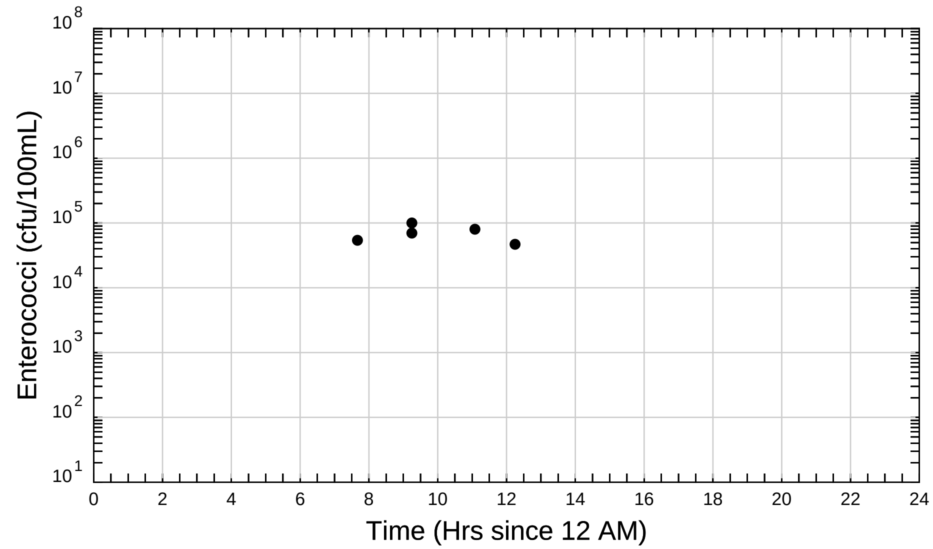


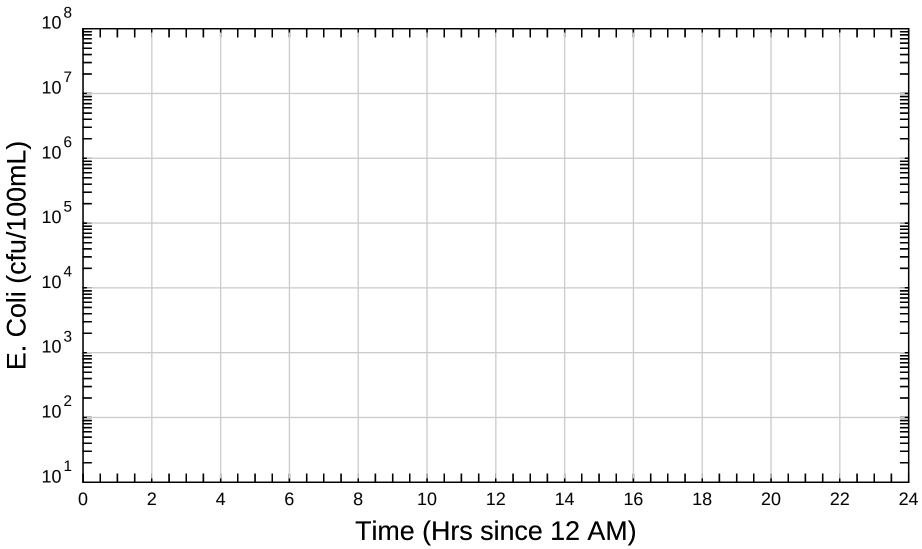


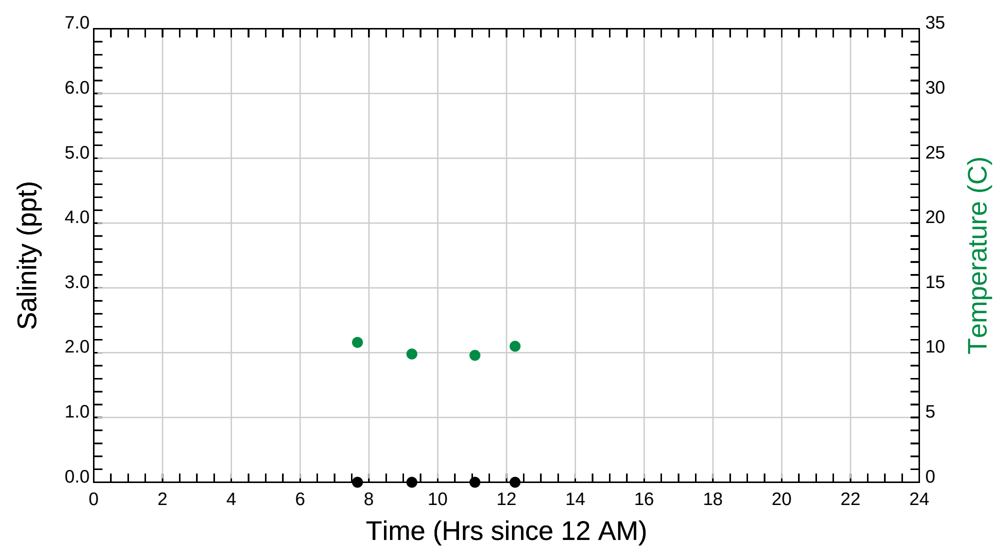
Wet-Weather Event 11. 15. 2016.

Station: S1-NWK-HR1



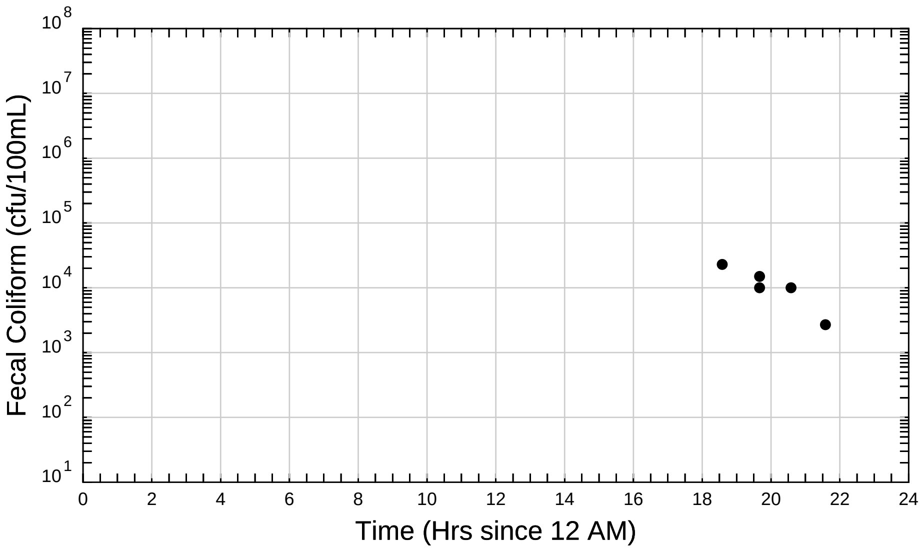


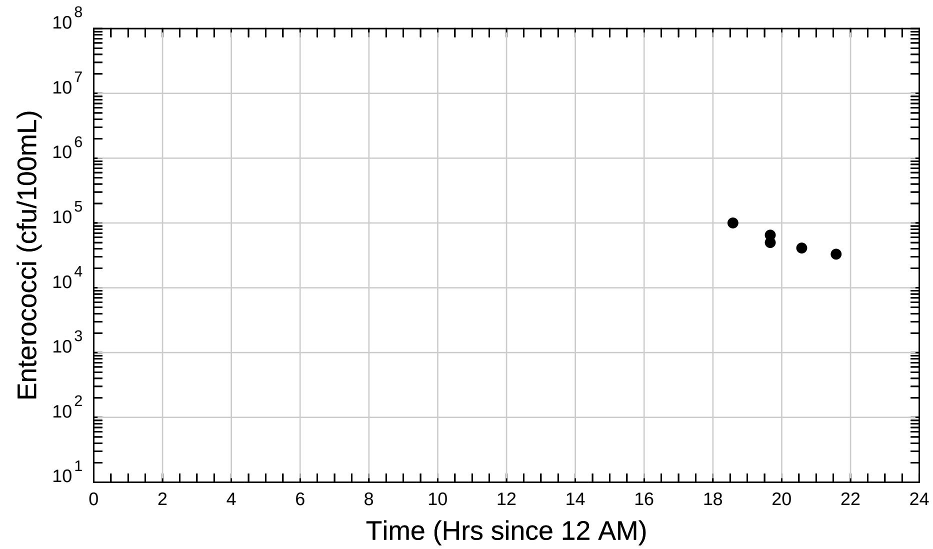


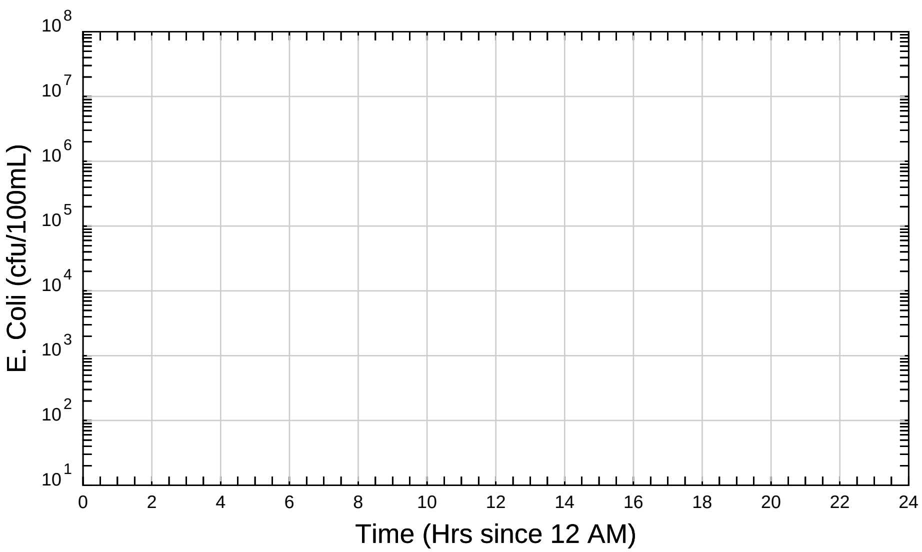


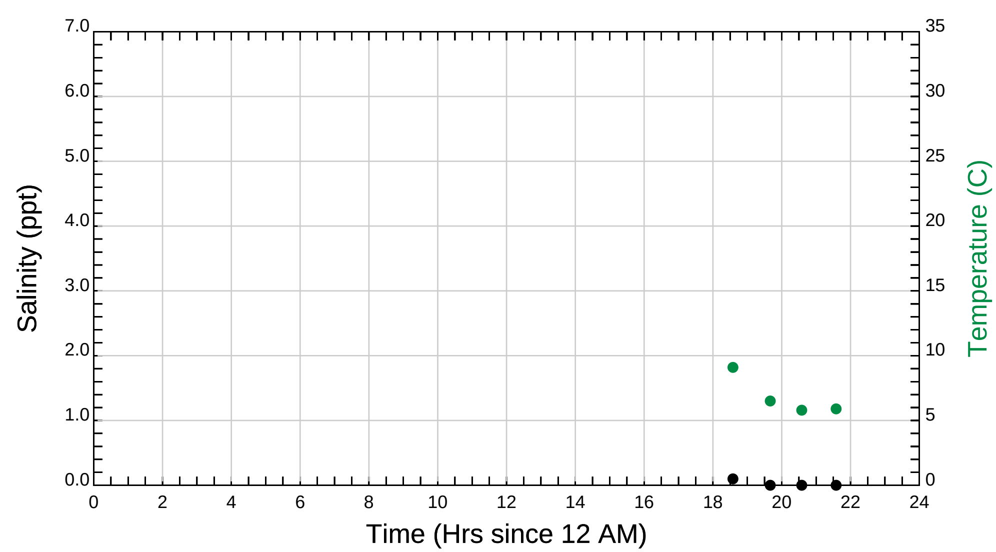
Wet-Weather Event 12. 6.2016.

Station: S1-NWK-HR1



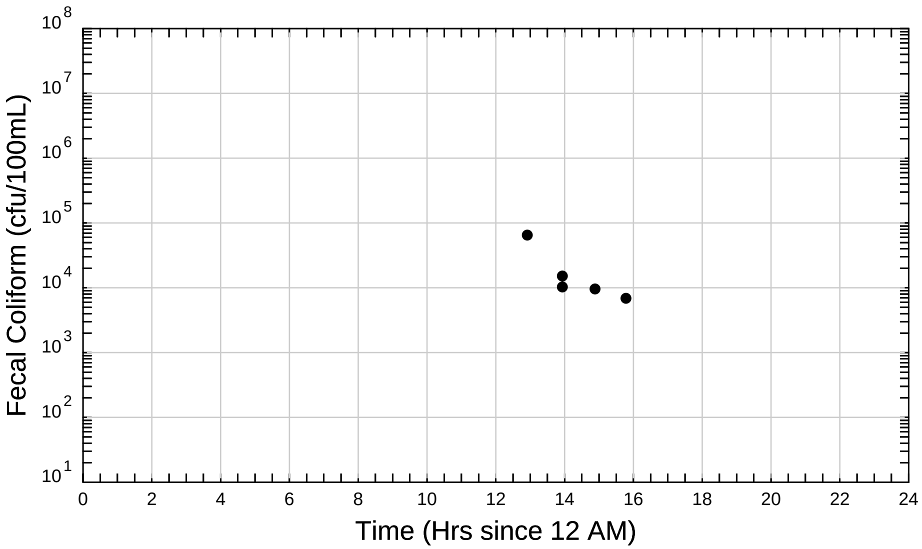


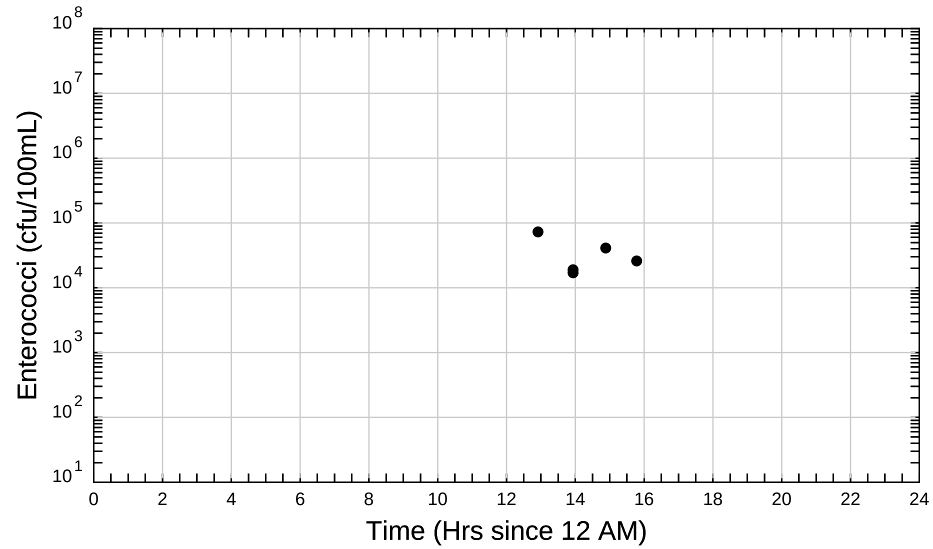


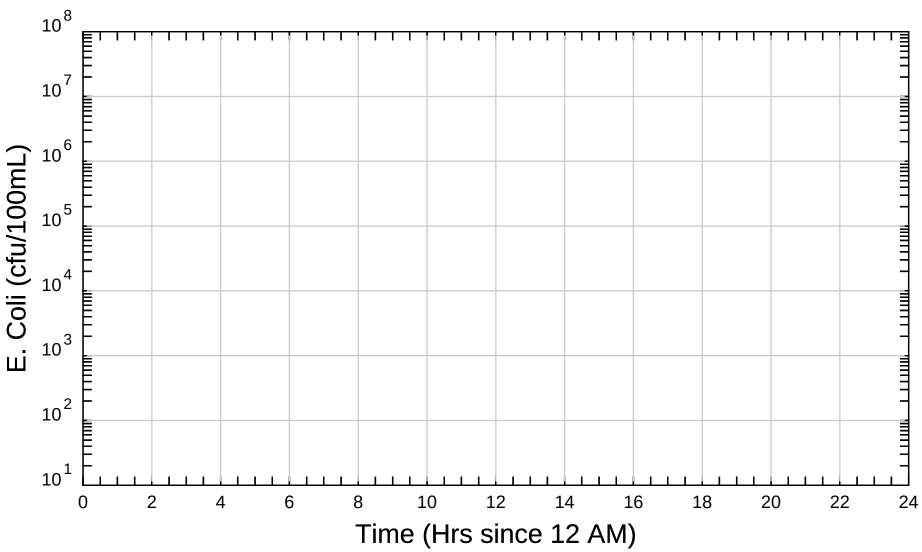


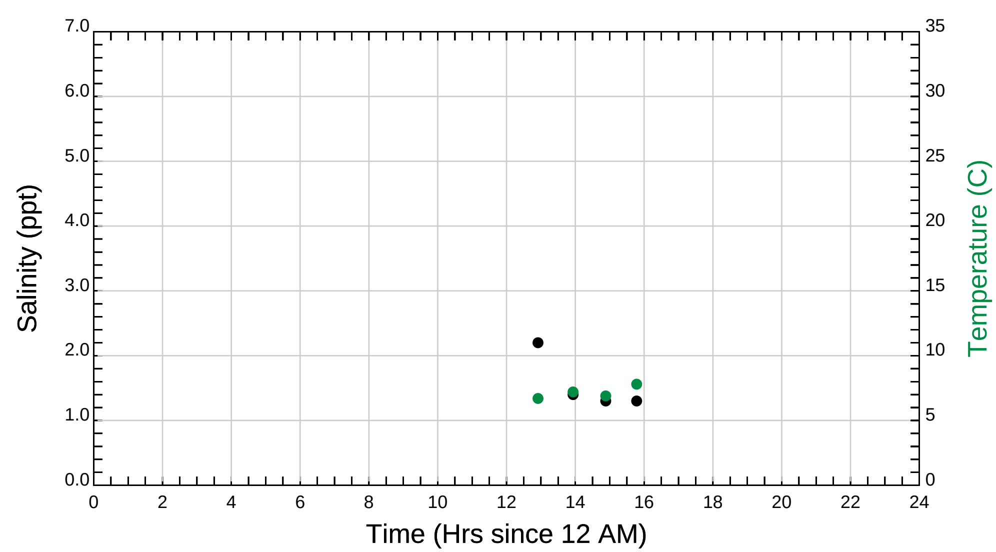
Wet-Weather Event 1. 17.2017.

Station: S1-NWK-HR2



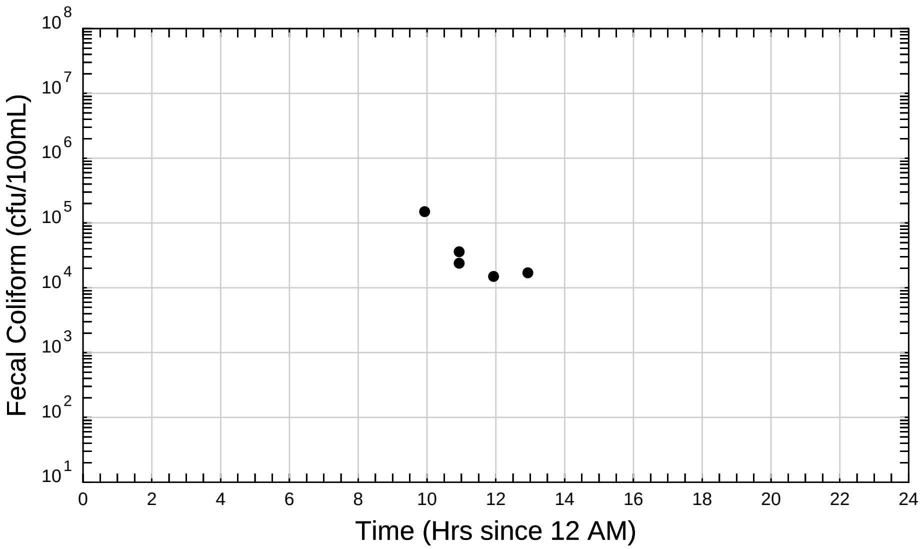


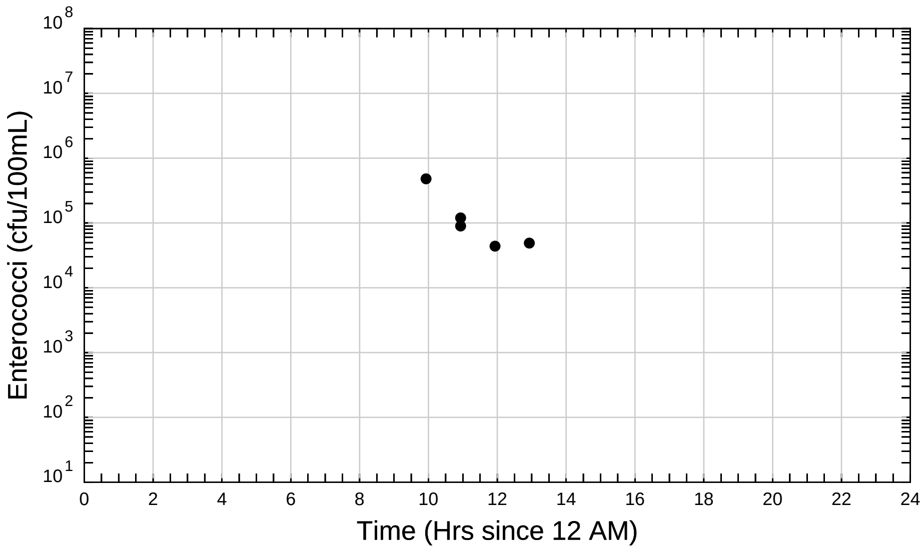


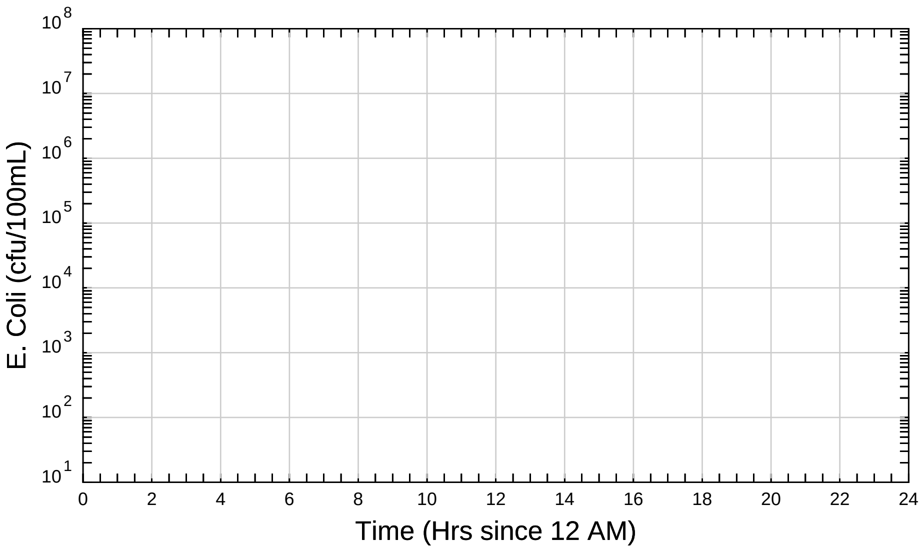


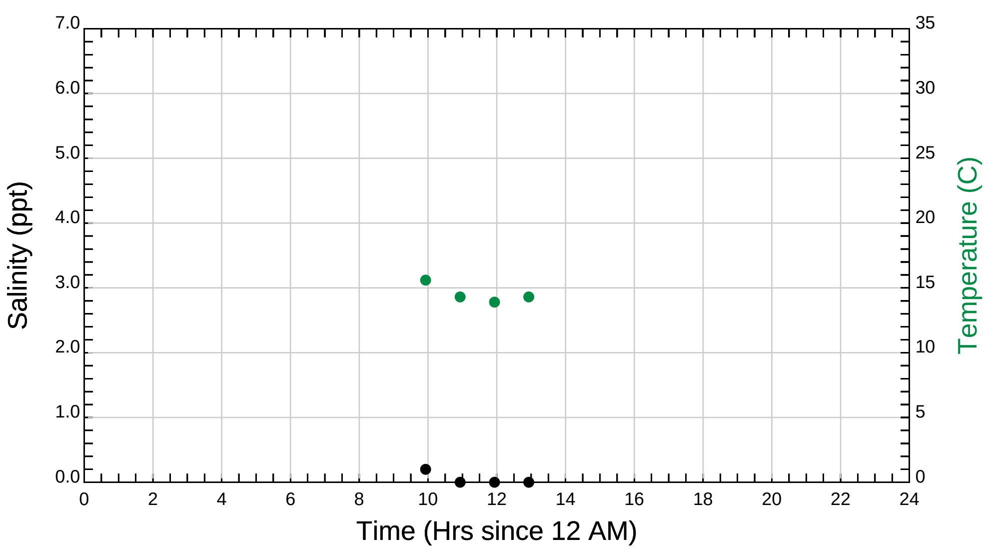
Wet-Weather Event 5. 5.2017.

Station: S1-NWK-HR2



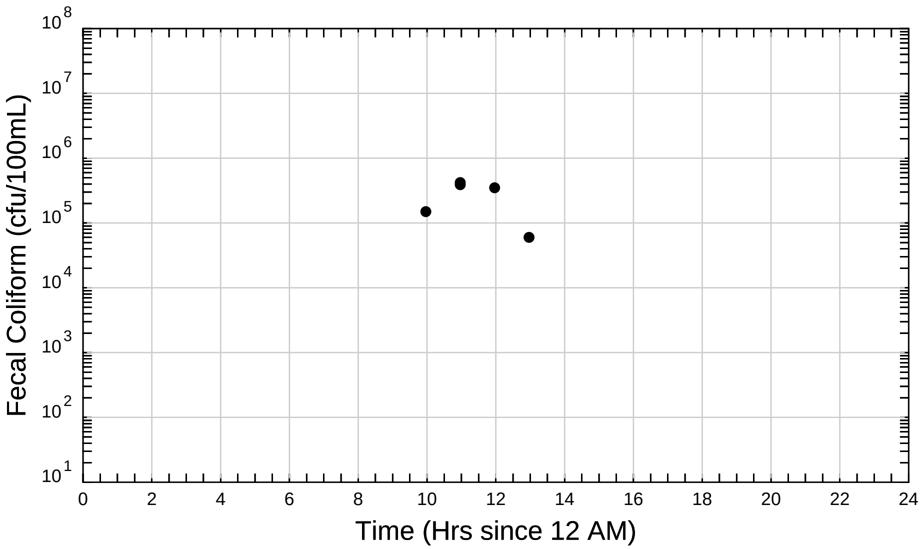


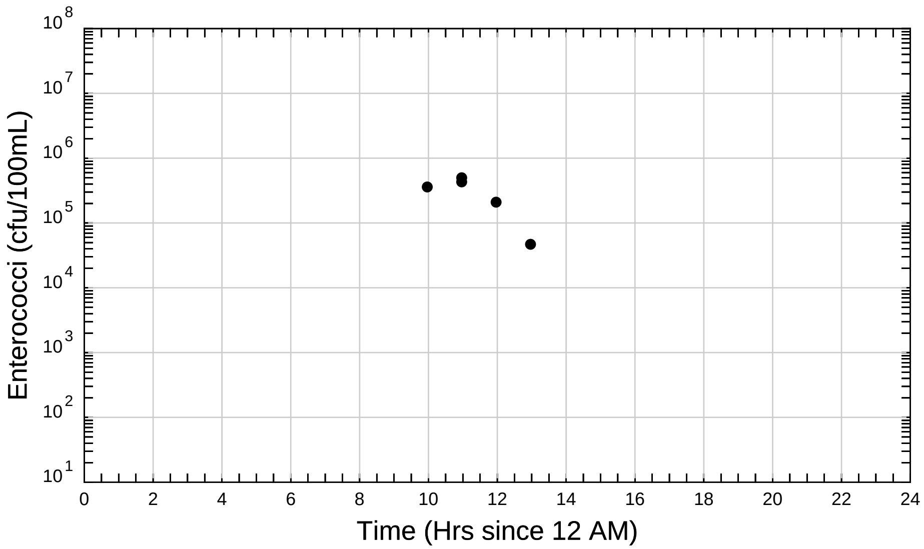


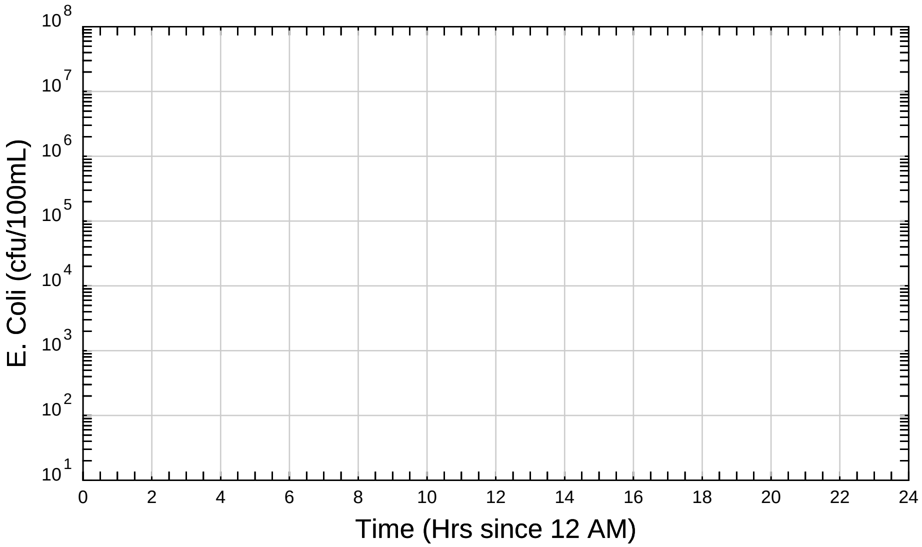


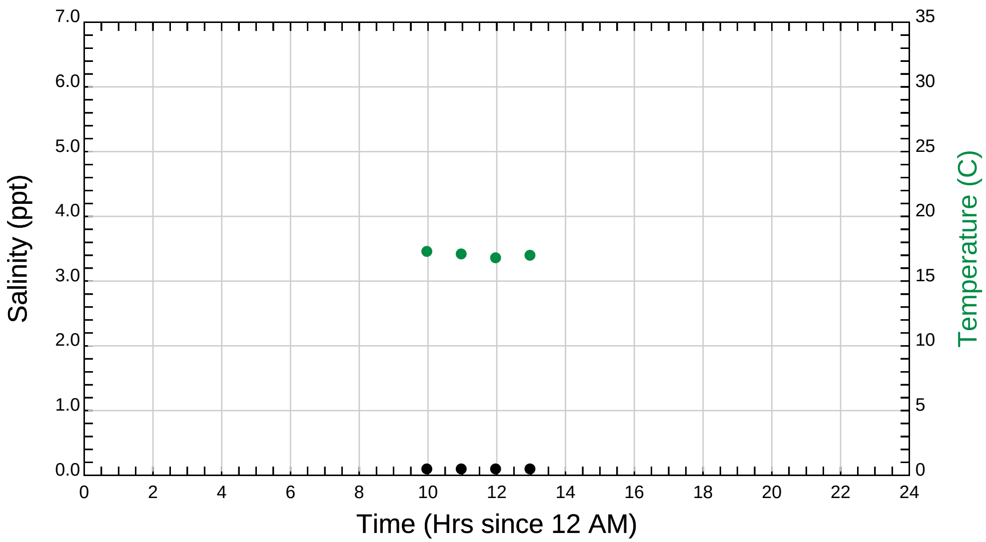
Wet-Weather Event 5. 22.2017.

Station: S1-NWK-HR2



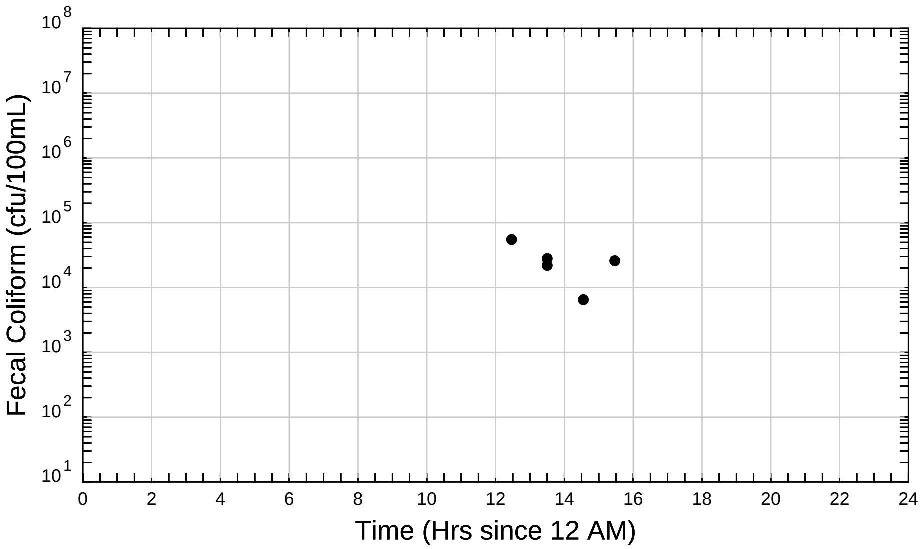


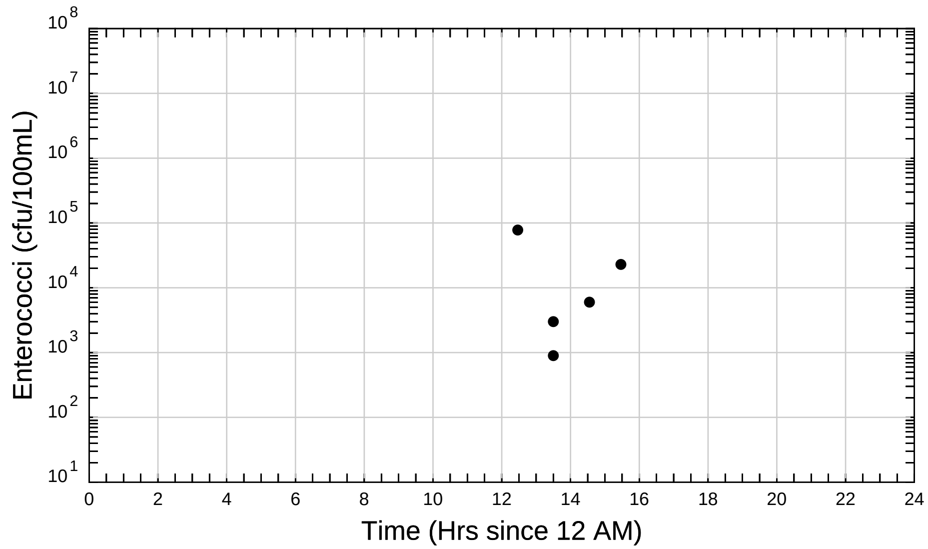


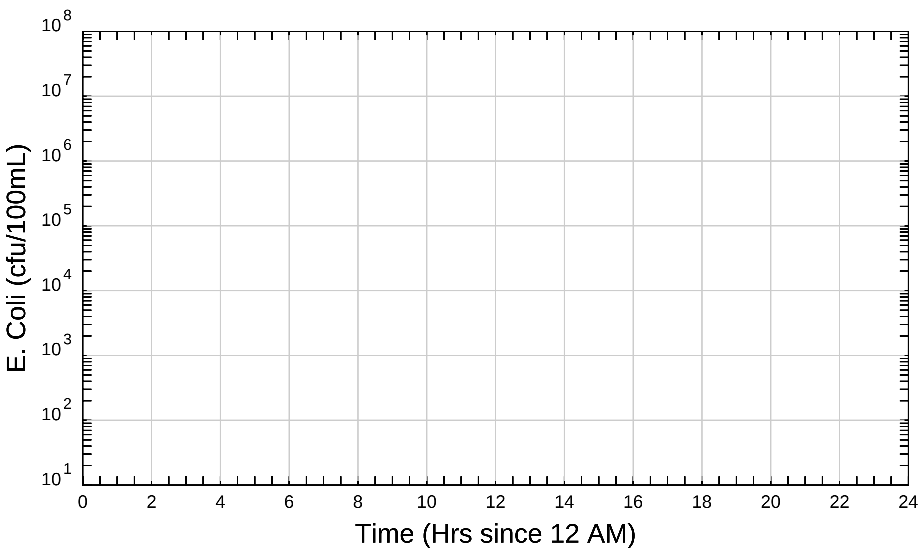


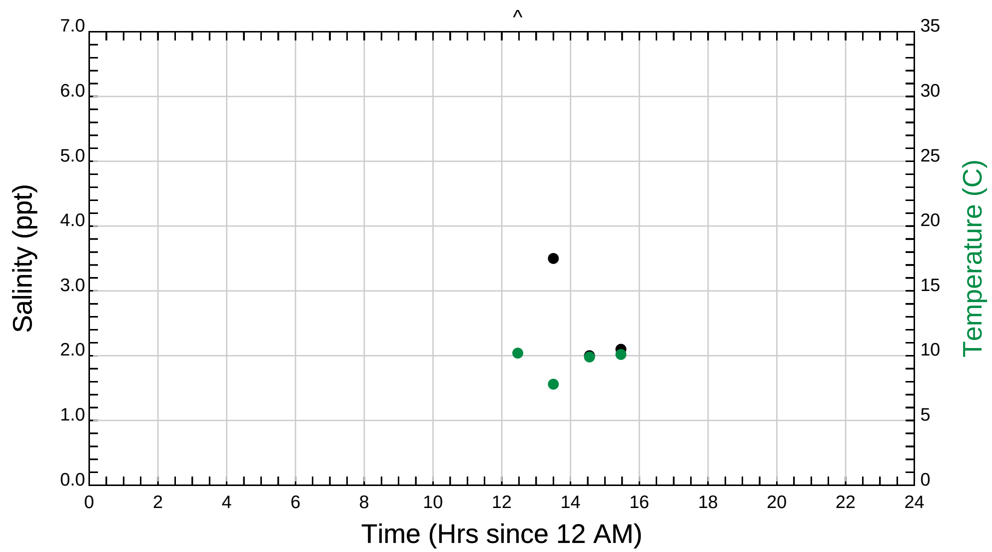
Wet-Weather Event 1. 17.2017.

Station: S1-NWK-LR2



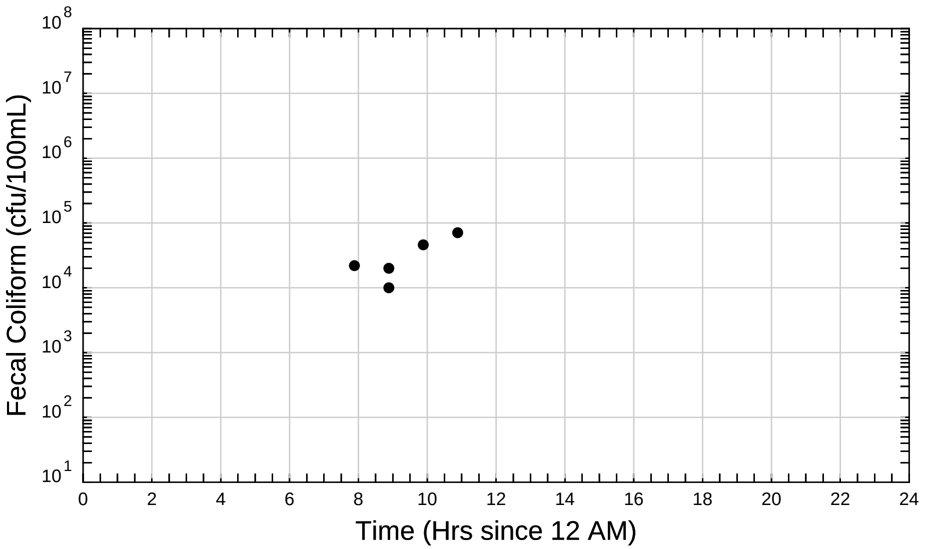


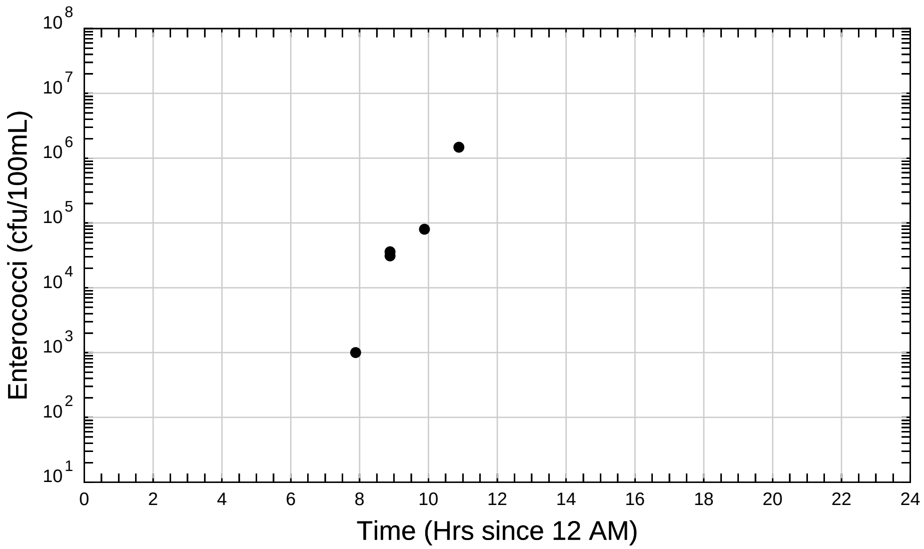


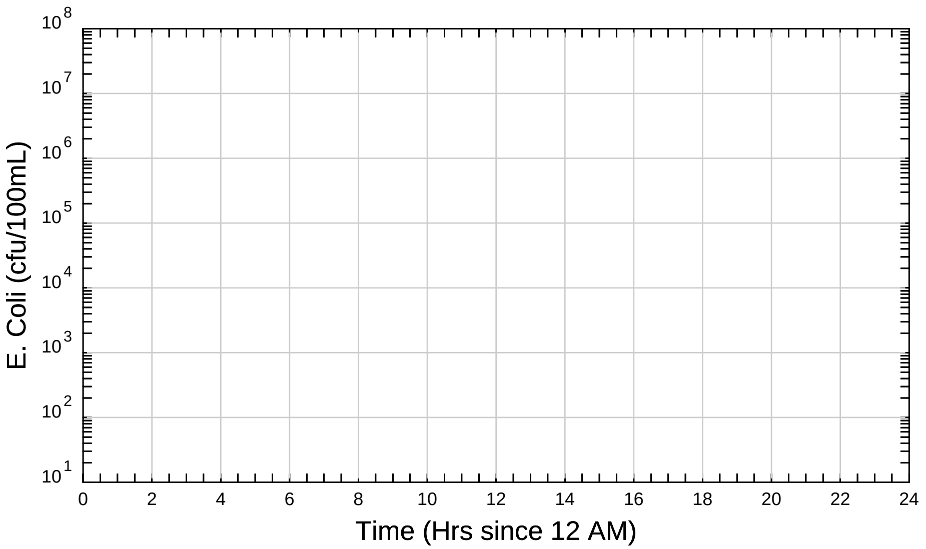


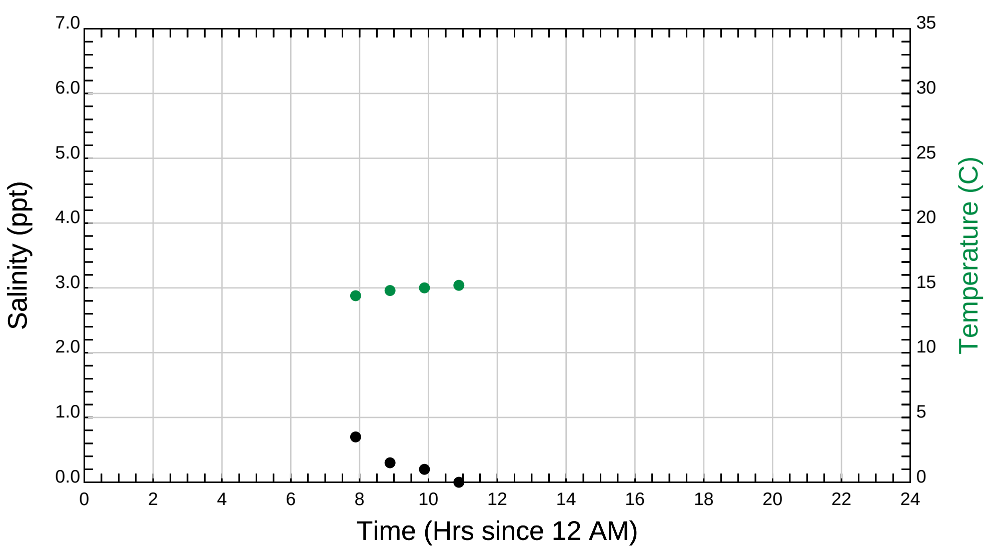
Wet-Weather Event 5. 5.2017.

Station: S1-NWK-LR2



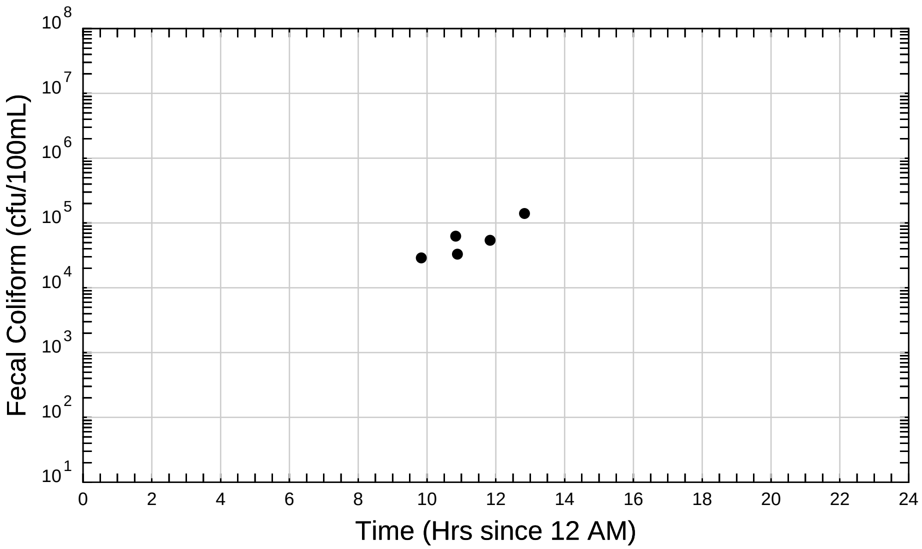


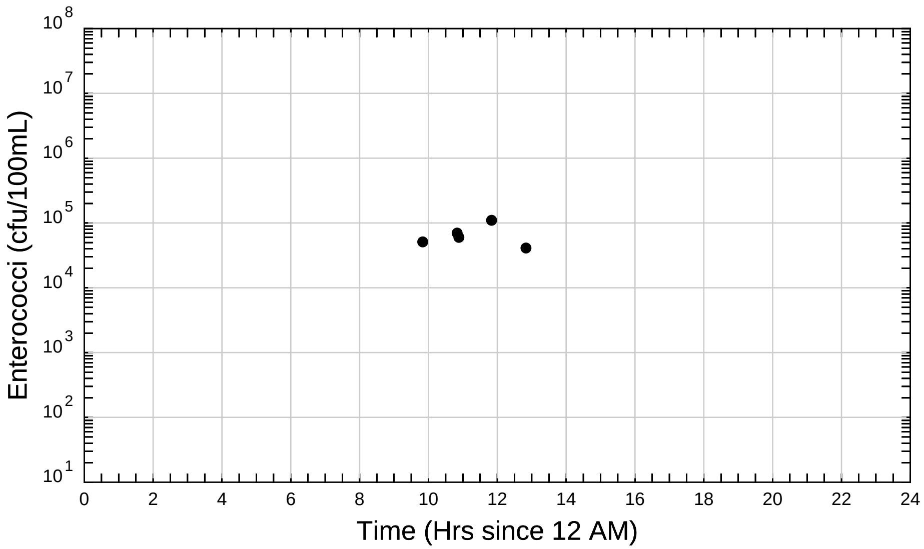


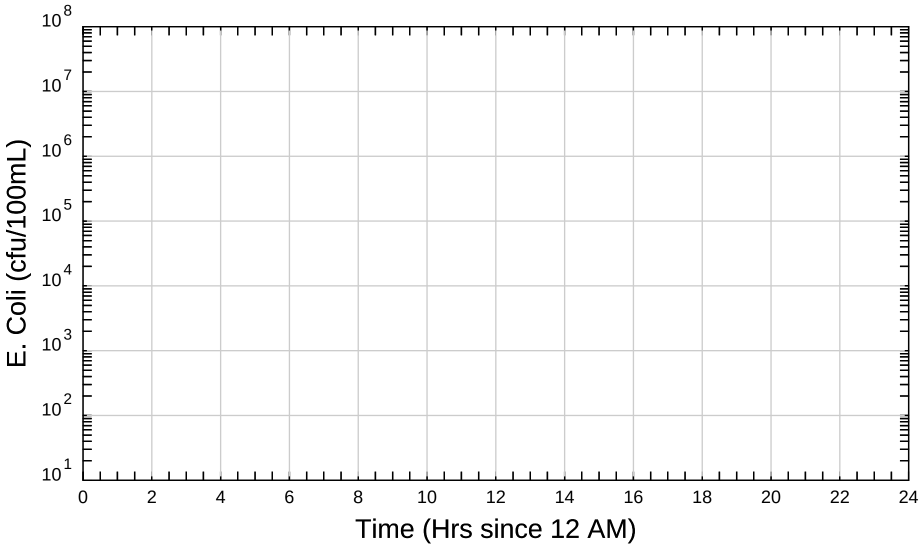


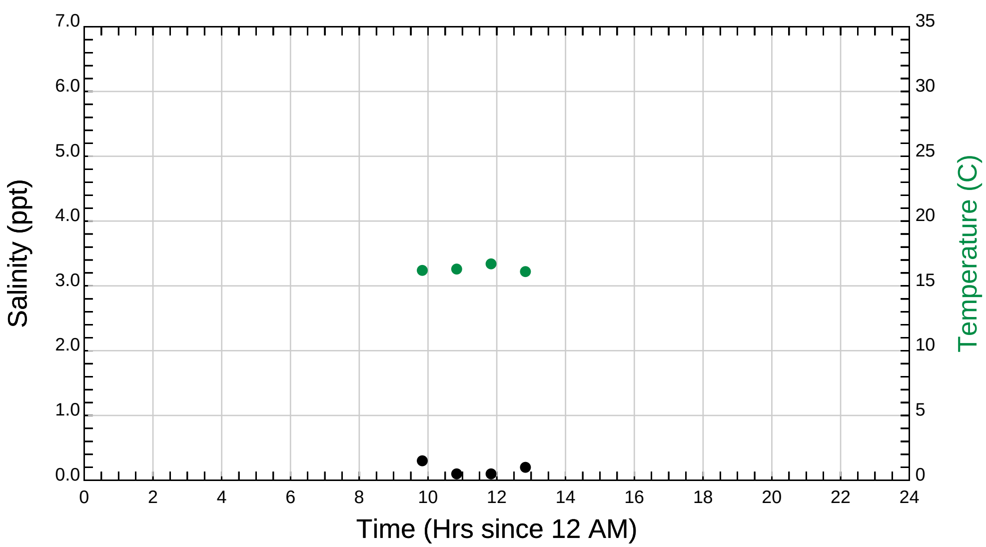
Wet-Weather Event 5. 22.2017.

Station: S1-NWK-LR2



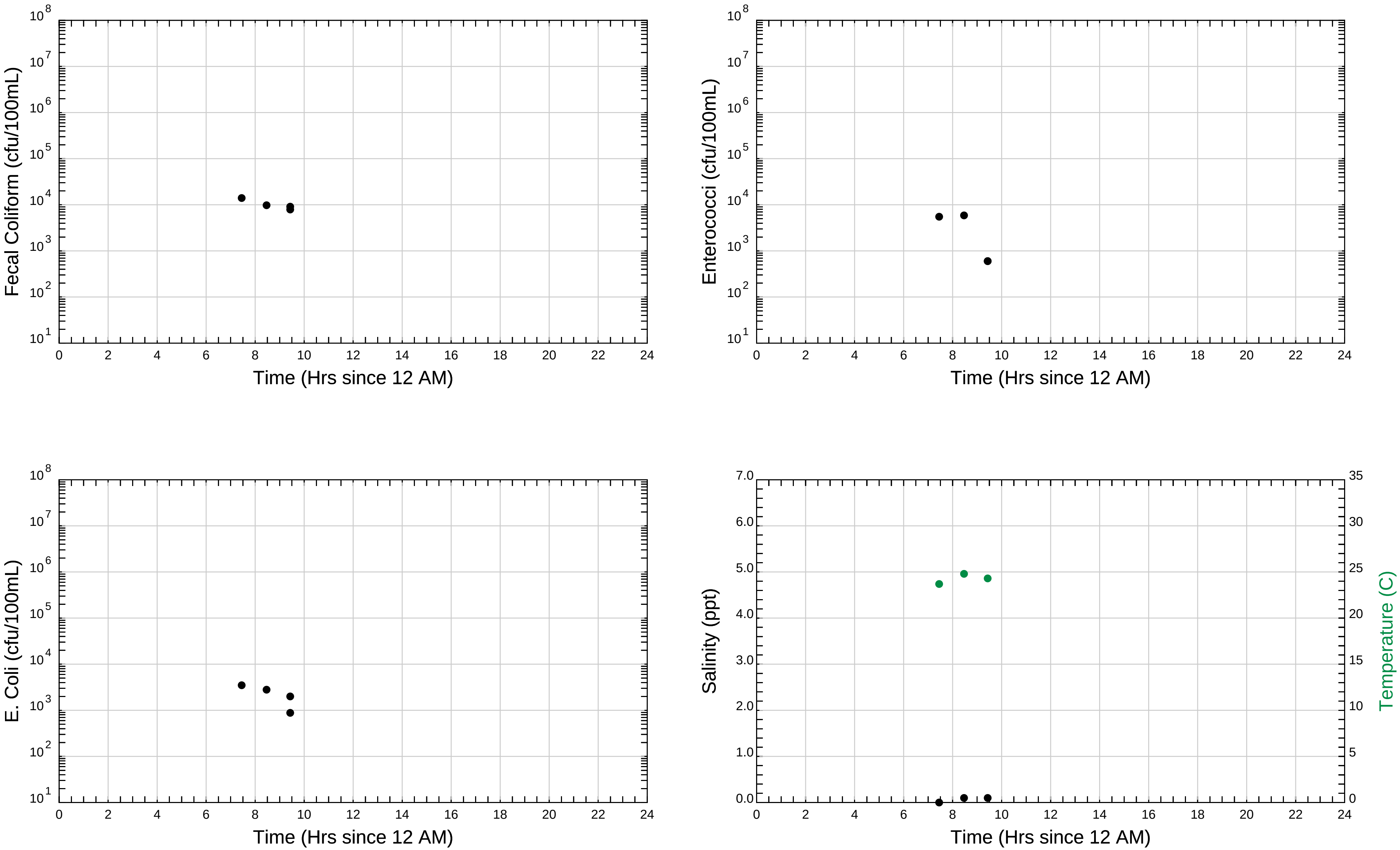






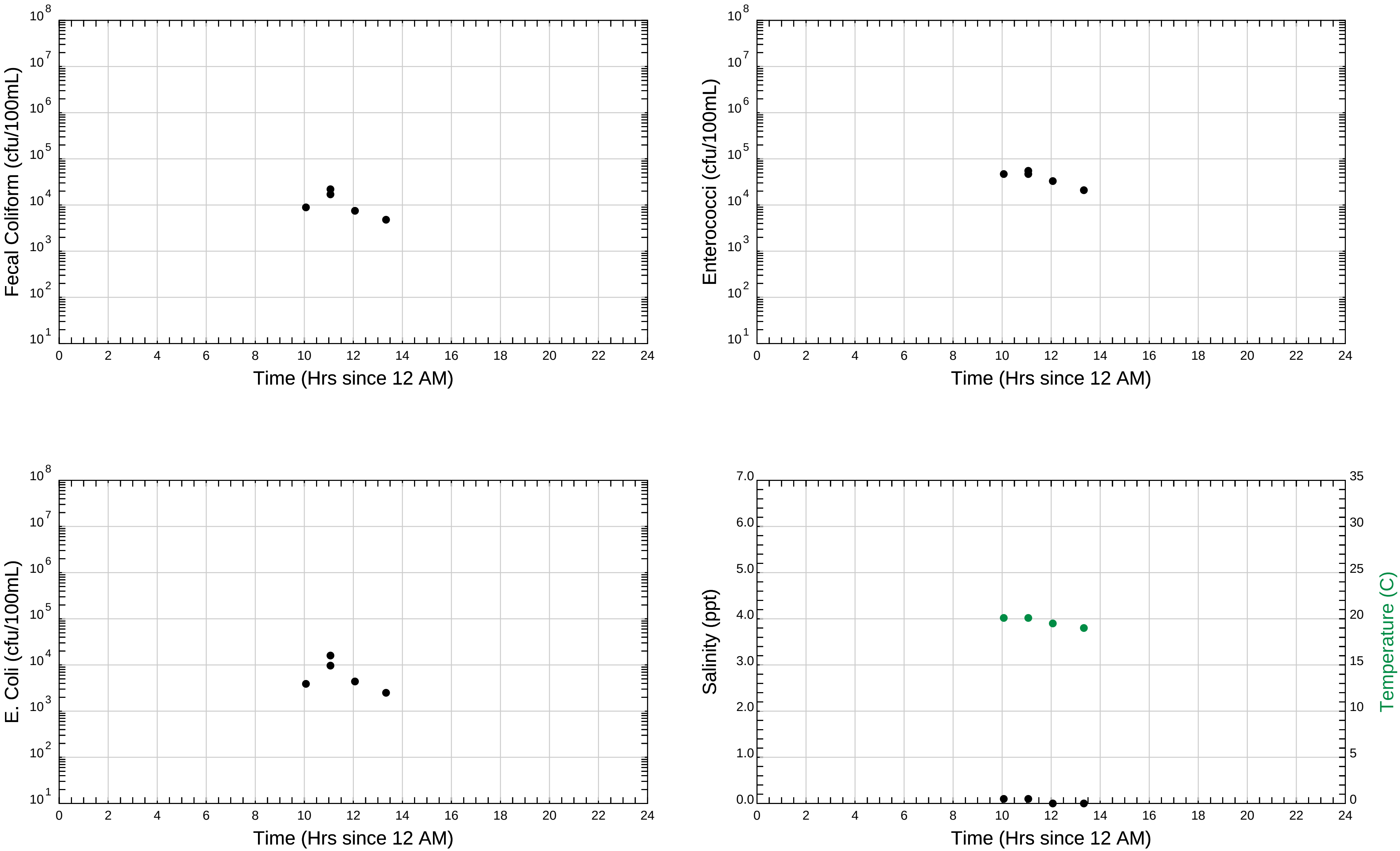
Wet-Weather Event 7. 29. 2016.

Station: S1-OAK-LR4



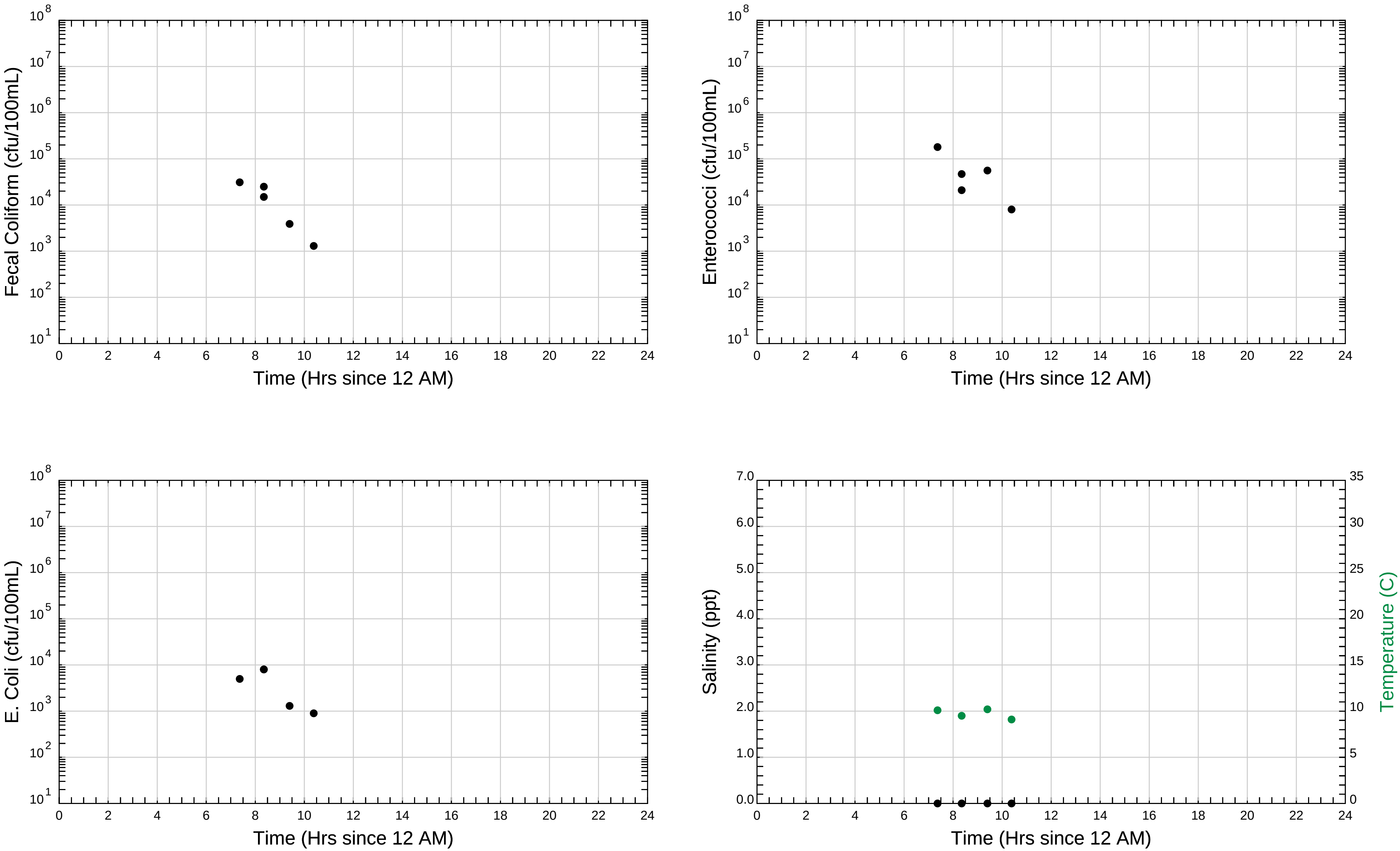
Wet-Weather Event 9. 30. 2016.

Station: S1-OAK-LR4



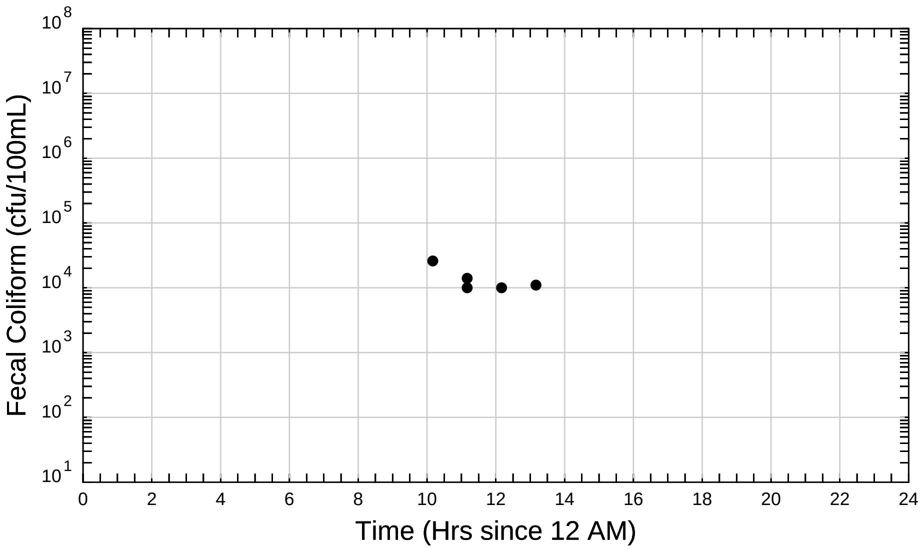
Wet-Weather Event 11. 15. 2016.

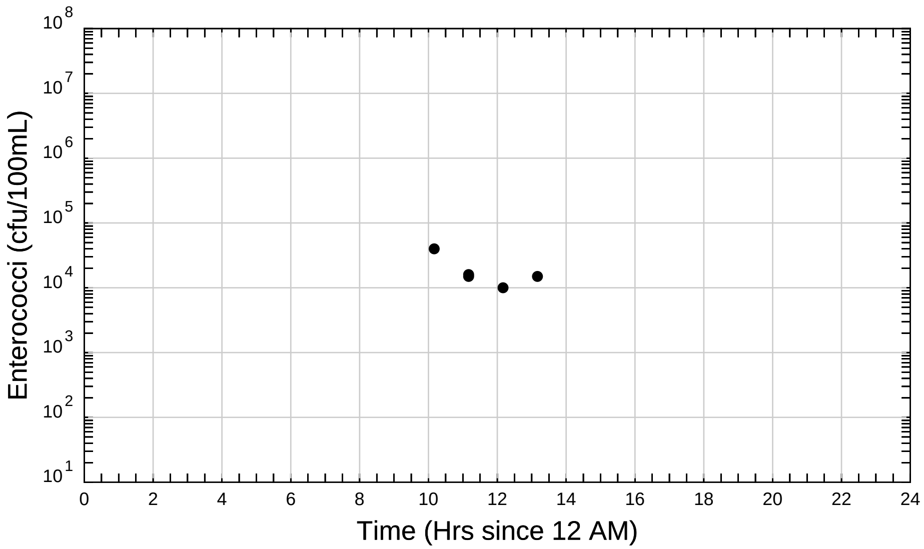
Station: S1-OAK-LR4

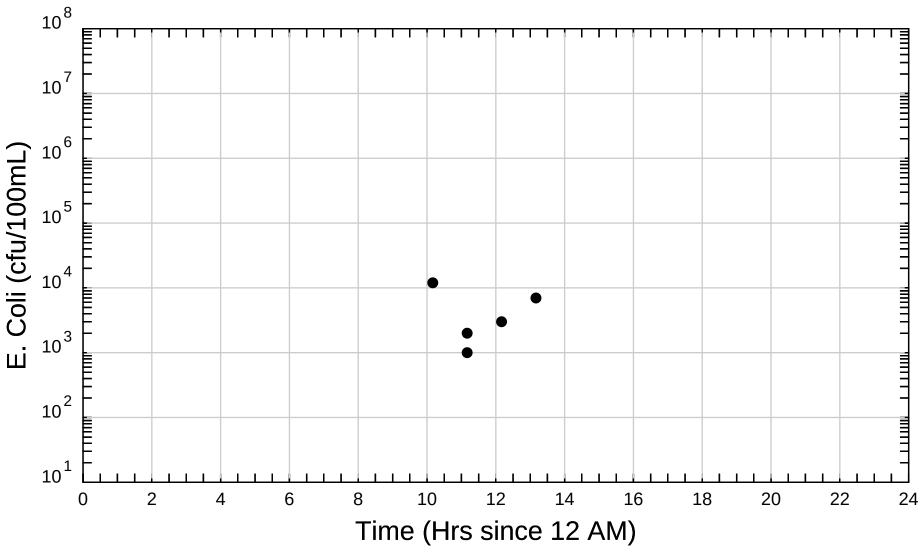


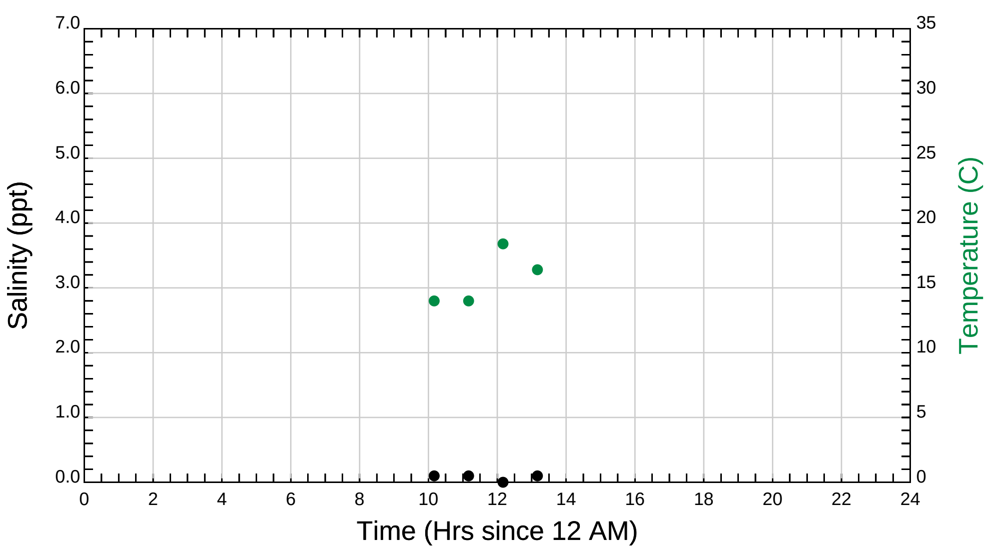
Wet-Weather Event 5. 5.2017.

Station: S1-PAT-CI1



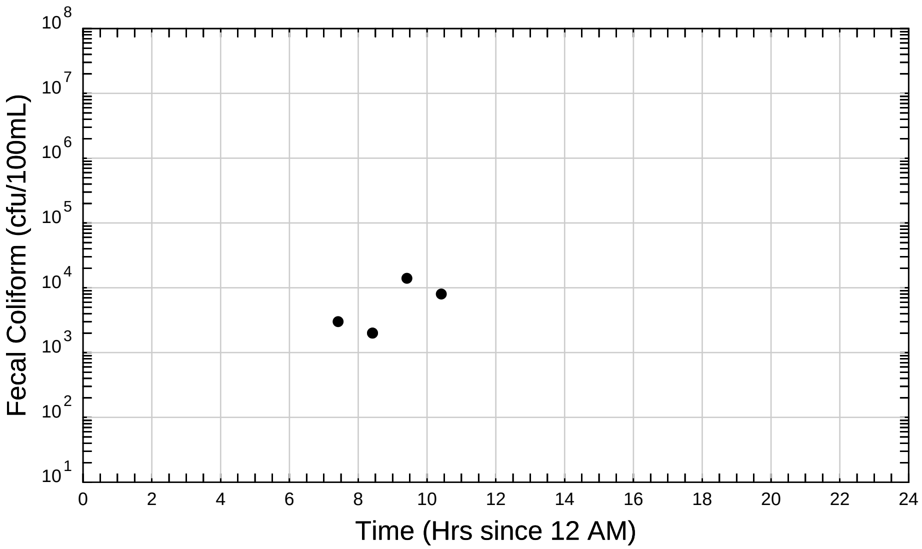


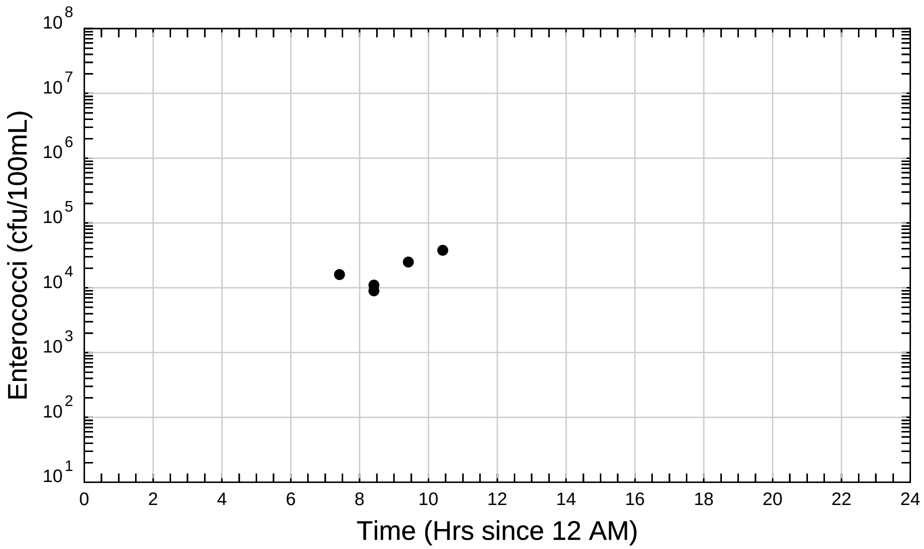


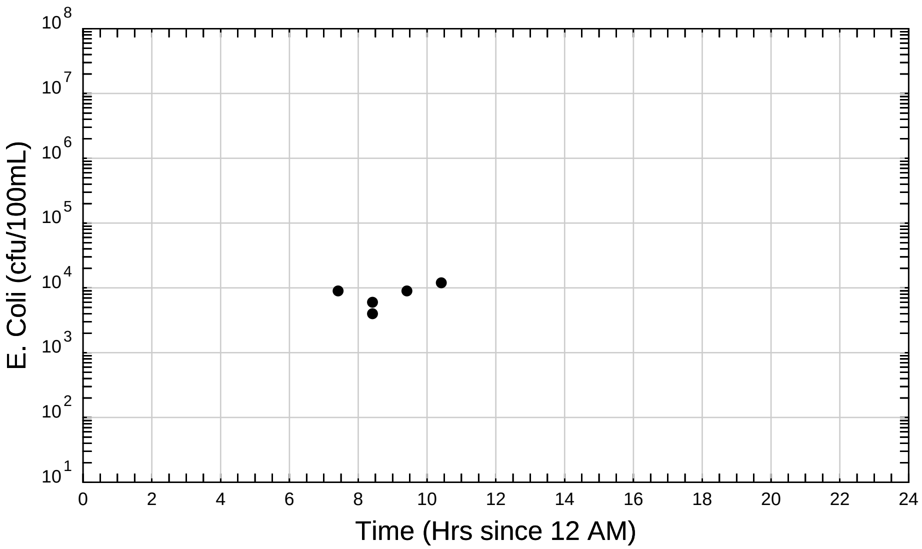


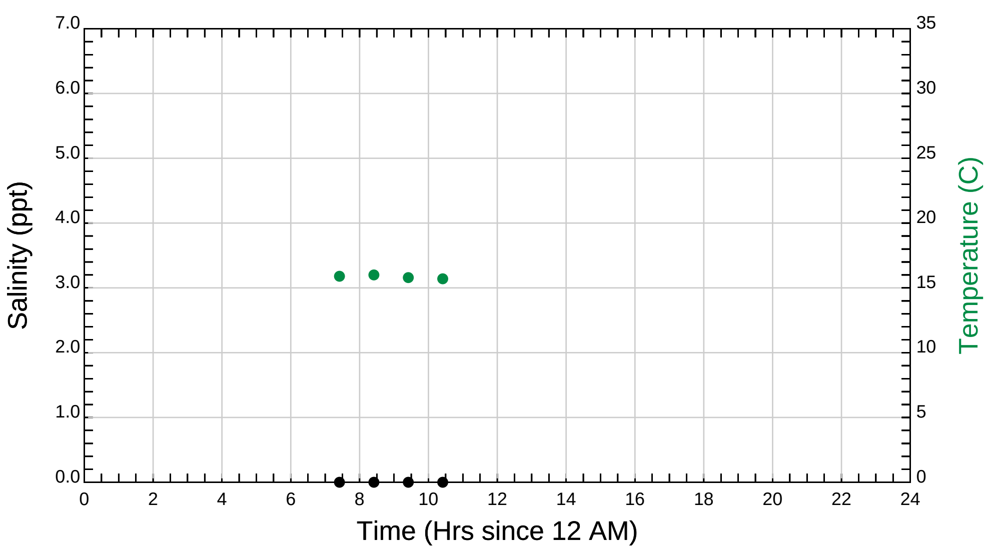
Wet-Weather Event 5. 25. 2017.

Station: S1-PAT-CI1



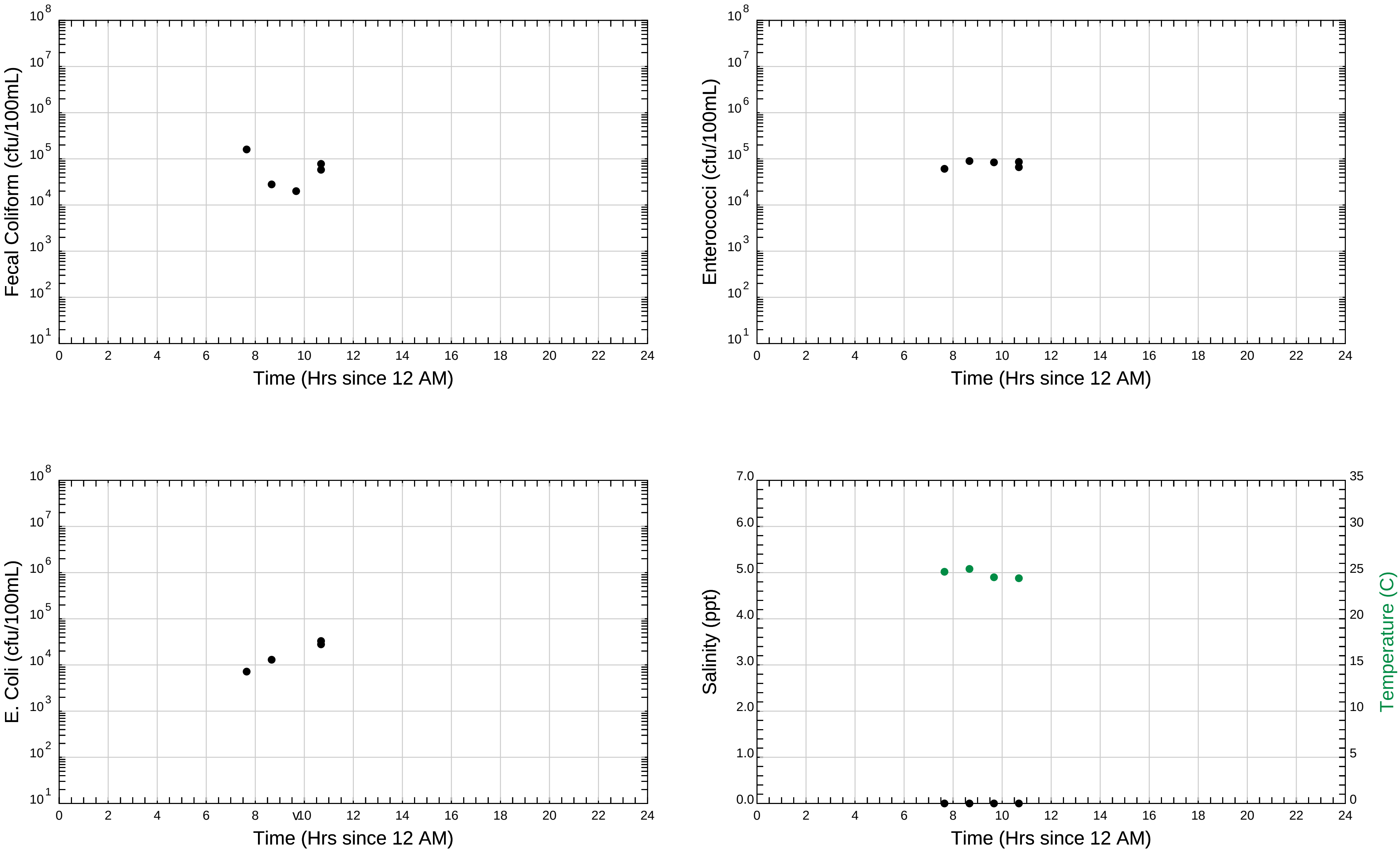






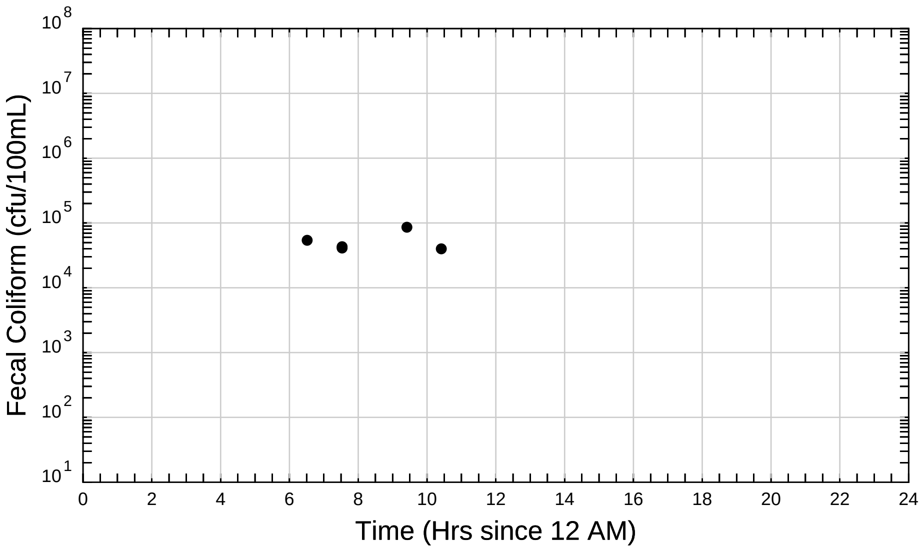
Wet-Weather Event 7. 29.2016.

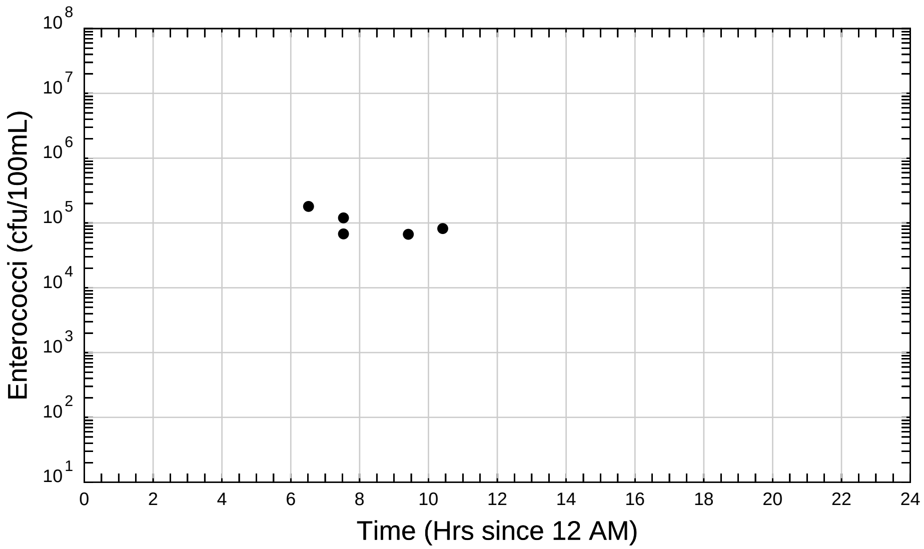
Station: S1-PAT-LR1

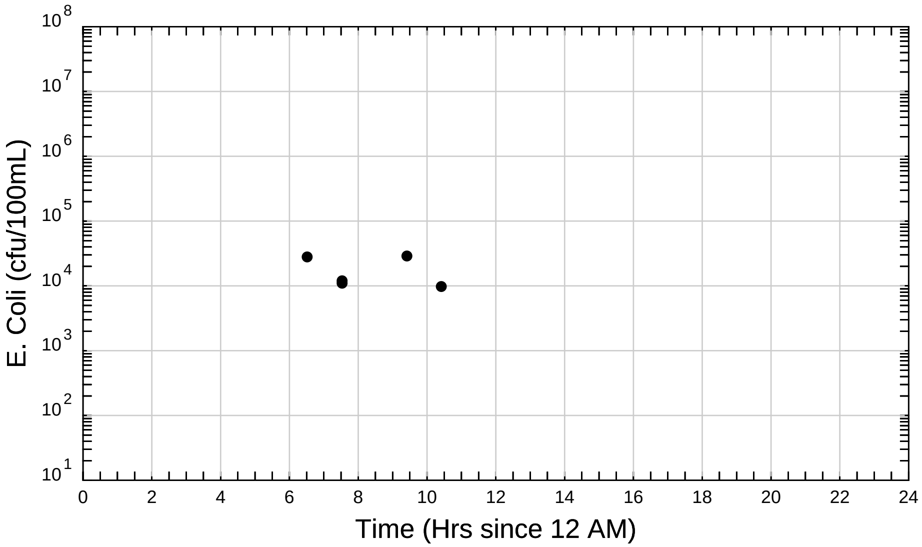


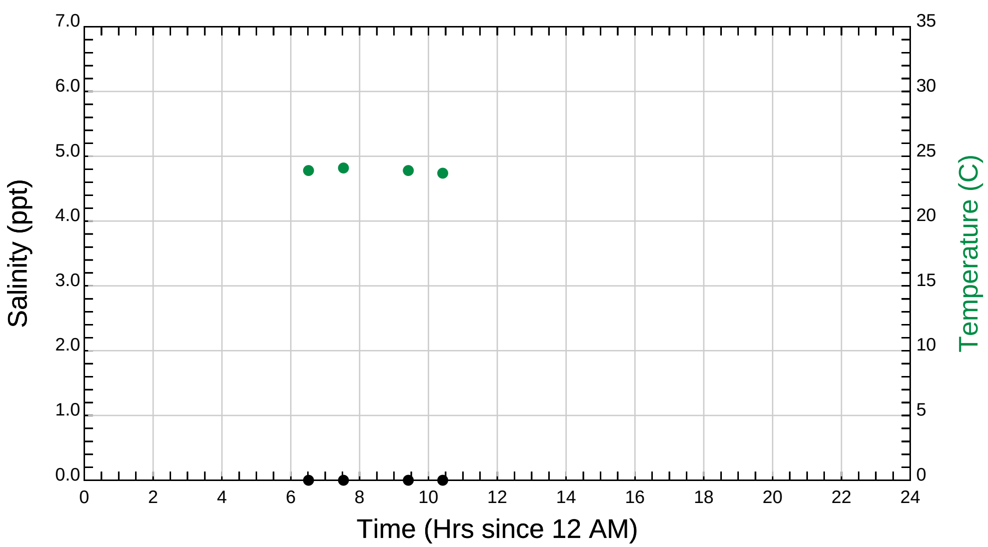
Wet-Weather Event 9. 19. 2016.

Station: S1-PAT-LR1









Wet-Weather Event 11. 15. 2016.

Station: S1-PAT-LR1